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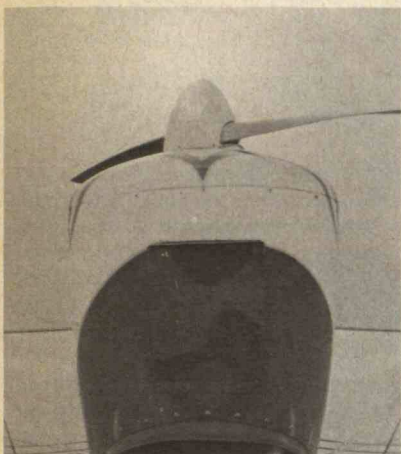
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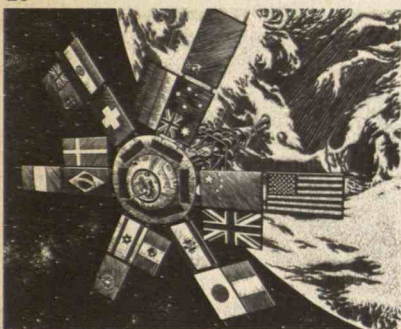
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LETTERS

Engineer's Lament

Lotte Bailyn's "Resolving Contradictions in Technical Careers; or, What if I Like Being an Engineer?" (*November/December*, page 40) does not reveal the true causes of dissatisfaction among engineers. True professionals manage their own funds, borrow and spend as required, and are free to form associations and partnerships as their practice expands. A technical "professional" in industry is just another employee who is hired, directed, reassigned, relocated, laid off, or fired at will by management. The engineer's problem in corporate America is that he or she is not a professional. Despite dual career ladders or development programs, the engineer is still a tool of management.

Engineering schools should minimize the problems of maturing technical professionals by preparing students for the kind of treatment they may receive after working in industry for many years. Alumni should be invited to share their experiences with students. Career and placement offices should describe the types of jobs and salaries open to professionals with 20 years' experience. The university structure should be explained in detail. Engineering students would then know what to expect from their professions and how to plan their careers accordingly.

Peter B. Franz
Cheshire, Mass.

How can a firm motivate engineers to stay in the field and do what they do best? One way around the dilemma is to offer parallel routes for advancement in management and technical achievement. Comparable titles, responsibilities, and salaries for each rung of the ladder would provide opportunity and incentive in both departments. This would heighten managers' respect for the scientific and technical expertise they market and make the technical staff more aware of the nature of the business world. Like Damon and Pythias, each will realize that either would die without the other.

Eugene H. Harlow
Houston, Tex.

Professor Bailyn proposes a system similar to the specialist ranks introduced in the army after World War II for those entitled to promotion but not in the line of command. The idea is overdue. There is no shortage of engineers but rather a lack of

utilization of talent owing to the attitude that the nonmanagement person is a failure. All too many firms look for recent graduates and fail to see what they have in stock.

David L. Weisen
Newark, N.J.

Professor Bailyn responds: I agree with the substance, if not the phrasing, of what Mr. Franz writes: the fact that engineers have frustrated expectations of maintaining fully "professional" careers in technology explains many of their problems. Unfortunately, I am less than optimistic that the parallel routes suggested by Mr. Harlow, or the specialist ranks mentioned by Mr. Weisen, will help very much. There are few examples of successful dual ladders in industry. The difficulty, I believe, stems from the fact that while the technical ladder may define new titles and salary increases, it rarely includes commensurate advances in job responsibility and influence on technical decisions. And though the former is an important first step, only the latter will give mature engineers sufficient scope to contribute to their organizations in accordance with their abilities and experience.

Whodunit in Detroit

Martin Anderson's "Shake-Out in Detroit" (*August/September*, page 56) overlooks the real cause of the problems of the American auto industry: auto magnates' total disregard for the public. Detroit, with few exceptions, has not produced cars that ride as well, handle as precisely, stop as surely, last as long, burn as little gas, and need repair as infrequently as most European, and now Japanese, cars. Mr. Anderson asserts that Detroit missed its opportunity by waiting until 1973 to begin on a *smaller* car. But Americans started buying European cars shortly after World War II. It would seem more accurate to say that automakers missed an opportunity in the late 1940s to begin thinking about building a *better* car.

Stephen Pomerance
Boulder, Colo.

Mr. Anderson's analysis of the ills of the auto industry deals too lightly with the self-satisfied myopia and selective inattention on the part of government. Throughout the 1960s, I stressed that the industry was already a two-time loser and

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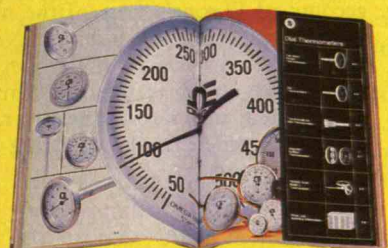
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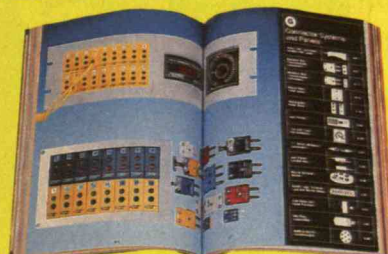
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in danger of a third and worse calamity. But the typical response was that Americans would never fall out of love with their full-size cars. When Honda announced its stratified-charge (CVCC) engine and demonstrated a similarly modified Chevrolet V-8 engine in 1973, the General Motors Research Laboratory did not have a single experiment on stratified-charge engines underway.

In a symposium on problems and prospects of U.S. transportation in 1974, Secretary of Transportation Claude Brinegar was asked why the government took little initiative in stimulating Detroit to produce better cars. He replied that the government would never interfere with free public choice. So things came to grief. As Immanuel Kant said of Fichte, "With such friends, what need have we of enemies?" David Rose
Cambridge, Mass.

Your two-page spread on smaller-sized American cars proven unsuccessful in the

marketplace included the "Crossley." It caught my eye because I had the distinction of driving one of the few station-wagon models on the road in southern Connecticut in the summer of 1953. But something seemed strange. A reference to Dutton's *Complete Encyclopedia of Motorcars* revealed three autos with similar names. The "Crosley" I drove was manufactured in Indiana. The "Crossley" was manufactured in Manchester, England. And the "Crosle" was manufactured in Belfast, Ireland. Your picture shows the Indiana vehicle, but the name is imported from England.

Joseph A. Dudrick
Sudbury, Mass.

Big Oil and Small Solar

Richard Munson and Barrett Stambler ("Competing for the Sun," November/December, page 12) ignore some real benefits stemming from the roles played by "big oil" and small solar companies.

The authors complain about "predatory prices" without appreciating the fact that heavy investment by large oil companies is a way of taxing present energy consumers to benefit future generations. On the other hand, small companies have an important niche in marketing low-temperature solar energy, the only solar technology currently competitive with traditional energy sources. Unfortunately, a few opportunistic photovoltaics promoters and their lobbyists want to feed at the trough of federal largesse. This does a disservice to the thousands of small companies that toil at the much more mundane task of helping small homeowners and business owners reduce their heating bills.

Peter Gottlieb
Los Angeles, Calif.

U.K. in Distress

Lord Zuckerman presents a well-reasoned account of Europe's view of the nuclear arms race ("How to Win the Nuclear Arms Race: A View from Europe," November/December, page 30). Unfortunately, the British flag on the cover, illustrating his article, is shown flying in the "distress" mode.

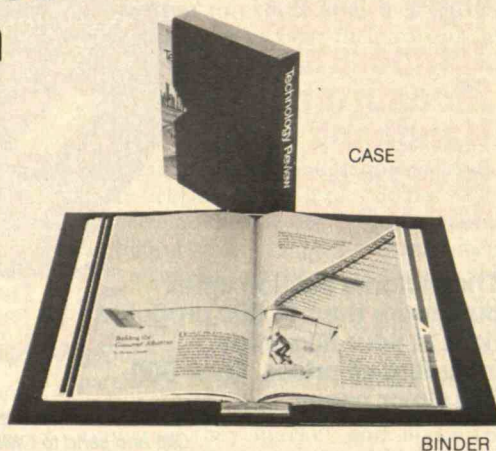
Michael Michaelis
Washington, D.C.

The nuclear squeeze exerted by the United States and the Soviet Union has not yet pushed us to a point where we need to signal our distress so graphically!

D.S. Oliver
Merseyside, U.K.

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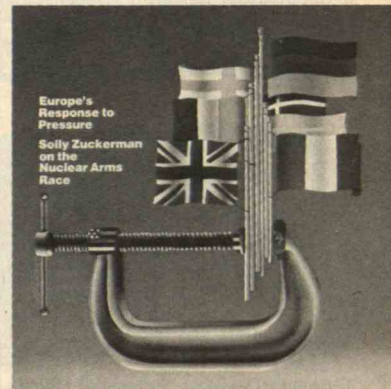
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The editors thank the sharp-eyed readers who pointed out that the Union Jack is subtly but nonetheless unambiguously asymmetrical.

Are any of your relatives diabetic?

There's a chance you are, too!

If anyone in your family has a history of diabetes—even a distant relative—treat it as a symptom! It should prompt you to have regular checkups because you are at greater risk of having the disease. Especially if you are overweight and over 40.

What is diabetes?

Diabetes is a disorder in which the body cannot control the levels of sugar in the blood. Normally the hormone, insulin, regulates the blood sugar level. But if your body does not produce or effectively use its insulin, diabetes results. Diabetes can threaten heart, vision, brain, kidneys and life itself.

What can be done about diabetes?

Often people don't realize that most diabetes can be easily managed by simple programs that bring blood sugar under control. Many diabetics need only weight reduction, the right foods and moderate exercise. And, if these changes are not enough, a simple oral medication is all that may be needed. Today, even those who need insulin can be better and more comfortably managed by their doctors than ever before.

Who has diabetes?

You'd be surprised at how many of your friends and fellow workers are diabetic yet lead full lives with no outward signs of illness. Even many famous athletes and celebrities have diabetes. With current therapy diabetics can usually lead a normal life with simple and sensible medical programs.

What are the symptoms of diabetes?

Warning signs are either absent or very subtle. You may drink more water than normal or urinate more frequently. There may be slower healing of bruises, cuts and infections, or you may experience more fatigue and feel "not quite right."

How will you know if you have diabetes?

You won't. Your doctor will. And again, if there is diabetes in your family—including cousins, aunts, uncles, brothers and sisters and especially a parent—then you should have regular blood and urine checks by your doctor. It is a relatively simple diagnosis.

Only your doctor can prescribe treatment.

Follow your doctor's advice about diet, exercise and medication. Also, be aware that you have a support system, which we call...

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IS CIGARETTE ADVERTISING A MAJOR REASON WHY KIDS SMOKE? NO.

Advertising is consistently ranked among the least important factors influencing college students to start smoking, according to a study by a professor of psychology who heads a prominent university research center.

That finding is typical. Because the fact is, cigarette advertising is not designed to induce people to start smoking, kids or anybody else. Its objective is to promote brand identification and brand loyalty among people who already smoke.

So why do kids start smoking? In a recent study of teenage smoking habits in which 1500 students were interviewed, the



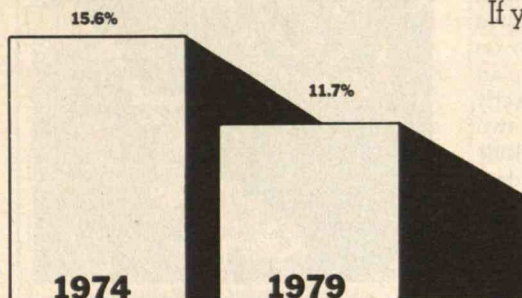
most asked questions about cigarettes.

students themselves named peer pressure as the most important influence in the initiation of smoking.

In a statement submitted at a recent congressional hearing, a noted California psychologist said that smoking behavior is a complex behavior determined by the interaction of several influences. This expert concluded that no single factor determines smoking behavior all the time.

Whatever the reasons for smoking may be, research shows that the smoking rate among teenagers has declined in the last several years. According to an American Cancer Society report based on a Government-funded study, teenage male smoking rates have dropped by one third to the lowest level since 1964.

This study revealed that during 1974-79, the relative decrease in smoking rates among teenage males was 32 percent. Among teenage females, 17 percent. Overall (see chart), the relative decrease among teenagers was 25 percent.



The relative decrease among teenage smokers was 25 percent during 1974-79.
Source: 1979 "Teenage Smoking" study for U.S. Department of Health and Human Services.

A more recent study conducted for a Government agency showed continuing declines among teenagers through 1981.

We think that's good. Because we think kids should not smoke. Smoking is an adult custom based on mature and informed judgment.

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Astronomy: Rock Records

WHEN spring arrives each year in the North American Southwest, it is widely greeted by what archaeoastronomer Robert A. Preston calls a "magical" interplay of light and shadow on rock. On June 21 summer is likewise saluted. Scientists have only begun to appreciate the accuracy and sophistication of the Indian petroglyphs—ancient calendrical dating systems etched in rock—artfully placed to take advantage of naturally occurring light patterns.

A good example is the famed Anasazi "sun dagger" on Fajada Butte in Chaco Canyon, N.M. If the sky is not cloudy on March 20, then precisely at noon, an elongated triangle of light moves directly through the center of the smaller of two spirals carved into the butte face. On June 21, a bright sliver, shaped like a thin dagger, likewise moves vertically downward to bisect the larger spiral. At the winter solstice, two light slivers precisely frame the larger spiral. The light patterns form when the noon sun shines through gaps framed by three massive stone slabs that lean against the butte face.

These ancient Indian observation sites are well known. Holes carefully placed in the walls of structures have also been shown to serve an observational function, as in the case of the Hohokam adobe ruins at Casa Grande National Monument. But until this year, the sun dagger was the only reported instance of the petroglyph system.

Now Preston, by profession a radio astronomer at the NASA Jet Propulsion Laboratory in Pasadena, Calif., and his artist wife Ann have found 19 other sites with a total of 56 comparable petroglyph markers. At the January meeting of the American Astronomical Society in Boston, they showed slides, films, and other data relating to these sites.

In all, the petroglyph markers, with 89 calendrical interactions, are found over a 300-mile range from Fajada Butte to Gila Bend. This prompts the Prestons to suggest that the sites are yet more evidence that the vanished, largely forgotten prehis-

toric Southwest Indians were intellectually sophisticated and scientifically advanced. John A. Eddy of the High Altitude Observatory, who has pioneered the study of North American Indian astronomy, calls the new evidence impressive. So, too, does Kenneth Brecher of Boston University, an astrophysicist who also studies archaeoastronomy. But he warns that the Prestons' research is still preliminary, and that it will be especially important to monitor what happens at the sites at times other than the turn of the seasons. This research can show whether the petroglyphs serve uniquely as calendrical markers.

Ordering the Universe

The Prestons acknowledge that their discoveries are only a beginning. However, they are convinced that the new sites provide consistent evidence that the Indians maintained a widespread calendar system based on the petroglyphs. They speculate that hundreds or even thousands of astronomical petroglyph sites may eventually be found, offering an unusual opportunity to understand the thought processes of early U.S. inhabitants. As Robert Preston told United Press International: "Every society tries to put order in their universe. We do it with science and this was their form of order." He added, "It must have been very magical to them. It's still magical to me."

The sun dagger's designers appear to have taken advantage of a natural opportunity to create the calendrical observatory. Artist Anna Sofaer, who discovered the sun dagger six years ago, speculated that the Anasazi must have carefully maneuvered the slabs to achieve so precise an effect. However, Evelyn B. Newman and Robert K. Mark of the U.S. Geological Survey, and R. Gwinn Vivian of the Arizona State Museum, showed last year that the slabs probably were placed by a natural rock fall. This implies that they were careful observers and knew what they were looking for in locating petroglyph sites.

Precise Mechanics

It must have taken considerable dedication and persistence to establish the petroglyph markers. "They had to very carefully monitor these rock surfaces many times a year before they could start carving," Robert Preston said. "Obviously it



Ancient Indian petroglyphs, dating systems etched in stone. Forty-five days before and after the winter solstice, a wedge of orange sunlight points at the center of this large outlined cross (top) in the Anasazi Indians' Cave of Life in Arizona's Petrified Forest. The sunlit pointer (bottom) intersects the center of both circles to mark the summer solstice at Painted Rocks State Park, Ariz.



ROBERT C. COWEN is science editor of the *Christian Science Monitor* and former president of the National Association of Science Writers.

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was not an idle thing they did when they noticed interesting things happening on a rock. It was very important to their culture."

The markings are found both on cliff faces and in caves. In the Petrified Forest, a rock shadows a spiral petroglyph carved at the base of a butte eight feet away. A pointed shadow retracts through the spiral when the sun rises at the summer solstice. This uncovers a second shadow line cast by the rock that bears the spiral. This second shadow line instantly runs vertically through the spiral's center. The spiral is one of several markers at this site.

The Cave of Life is a small cave also in the Petrified Forest. During the winter solstice, three pointed images of light run tangent to the top and bottom of a circular petroglyph and pierce its center, interacting with a spiral carving. At the equinox, a shadow line cast by the setting sun's last light is precisely tangent to the same circle and spiral.

Equally fascinating and precise events occur 45 days before and after the winter solstice. A small light image traces the outer edge of another spiral. It moves on to fade out at sunset as an orange wedge with its point at the center of a large outlined cross surrounded by fertility figures. In all, 11 separate petroglyphs interact with light and shadow in 25 different ways to mark the solstices, equinoxes, and moments 45 days before and after the winter solstice.

These are Anasazi markers. The Prestons also found a Hohokam site near Gila Bend with two circles, a "lizard" figure, and a cross contained in a panel within a small, open-ended, natural box of rock. Three thin sunlight pointers move roughly horizontally across the panel at the winter solstice. One intersects the centers of both circles. The others are tangent to the circles, top and bottom. A sunlight pointer moving vertically downward at the summer solstice runs tangent to both circles. Then it divides into two pointers, one of which runs downward through the center of the cross. Finally, 45 days after the winter solstice, the same point of light that runs through the centers of the circles pierces the center of the cross. On the same day, the wedge of orange light fades out at the center of the cross in the Cave of Life, 200 miles away.

Work to establish whether these sites constitute evidence of a sophisticated calendrical system should be done as quickly as possible. Many reported sites, as well as hundreds not yet studied, are unprotected on private land, in danger of being mutilated if not entirely destroyed, says John Eddy. It would be tragic if we were to begin to appreciate the intellectual achievements of ancient Indians, only to have the evidence vanish through modern ignorance and carelessness. □

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Science for Public Consumption: More Than We Can Chew?

LIKE most people of goodwill, I have always believed that the public should be kept informed about science and technology. Facts for the masses, and the more the better. Only that way, in a democracy, can appropriate decisions be reached.

My faith in this premise, however, is occasionally shaken—most recently in my dentist's office. I asked why a cracked silver filling was to be replaced with a costly gold inlay and was given various structural reasons that were more or less convincing. I agreed to my dentist's recommendation and was about to drift into the trance that I try to attain in such situations when he added something that made me suddenly alert. "Besides," he said, "these so-called silver fillings really are amalgams that contain a lot of mercury, and we're beginning to wonder about the possibility of this mercury leaching into the systems of our patients. I've been following the work of experimenters in Colorado, and pending further results I'm being a little cautious about using the stuff." When I told him that I had never heard of any such danger, he replied that it was not exactly the sort of information that the dental profession wants banded about. "The research is in very early stages," he explained, "and we don't want to frighten people unduly."

As he proceeded with his work, my mind started to race. A potential catastrophe! Tens of millions of people—one of them me—with insidious mercury leaching from their teeth into their vital organs. And what a scandal! Research was being performed and the findings were not being publicized. By the time I left the dentist's office, my alarm had subsided, but I determined to find out more.

My research consisted of obtaining a newsletter published by the Toxic Element Research Foundation (TERF) of Colorado Springs. Its single urgent message is that toxic elements have no place in the mouth. The four-page leaflet seems to be addressed mainly to dentists, but nothing in



it is technically obscure. Unfortunately, I can't tell whether the newsletter is the product of discerning professionals or the fantasy of a group of eccentrics. I suspect the latter, particularly since a section captioned "Strong Testimony" consists of an "unsolicited expression of appreciation" from a young man whose arthritic symptoms disappeared one week after two small amalgams were removed from his teeth. Yet the board TERF includes a D.D.S., an M.D., a biochemist, a psychologist, and the president of a bank. I am feeling healthy at the moment and busy with other concerns, so I guess that I will forget about the whole thing—unless I hear further from my dentist.

All Experts, All the Time?

I could pursue the matter, of course, but then how would I find time to keep abreast of the latest information on acid rain, the greenhouse effect, recombinant DNA, nuclear waste, new drugs, new diets, and a myriad of other technical matters that affect me and the society around me? It is all very well to speak of an informed public, but in truth we spend our lives relying upon experts.

This is not necessarily as distressing as it sounds. Lewis Thomas, writing about his newly implanted pacemaker, reports with surprise and amiable guilt that the theories he held as physician-philosopher have changed completely since he became a patient. "Don't explain it to me," he says. "Go ahead and fix it." A lot of

people seem to feel that way.

The conventional wisdom about maintaining a technologically informed public was challenged effectively a couple of years ago by Leon Trachtman of Purdue University. After a quarter-century devoted to studying, teaching, and science writing, Professor Trachtman (in the quarterly *Science, Technology & Human Values*) questioned what he had come to think of as a "glib assumption." Efforts to inform the public about science and technology were rarely effective, he concluded, either in improving individual consumer choices or communal policy decisions. "When there is a scientific consensus," wrote Trachtman, "there is no need to inform the public except to recommend a proper course of action. When there is no consensus, why inundate the public with ambiguous and contradictory reports?" And further: "Since the important issues are generally the ambiguous ones, more knowledge seems almost calculated to create greater uncertainty."

The argument impressed me very much and brought me to the verge of changing my mind. But when I spoke about it to a few people I respected, they all warned me not to adopt an elitist position.

Even as I write this column, an issue of *The American Scholar* arrives in the mail containing an article by Jeremy Bernstein entitled "Science Education for the Non-Scientist." Here it is again, the warning that unless we learn science, technological decisions will be made on our behalf—and to our regret—by others. (Of course, as Bernstein points out, there are other reasons to study science—not least for pleasure.) Bernstein is optimistic that a scientifically literate public can learn to make its own decisions, yet what does he offer to support his conviction? He tells of teaching a course to 14 science majors at Princeton and bringing in four experts in nuclear power, both pro and con, to address the class. By the end of the term, the class had been converted from unthinking opponents of nuclear power to grudging advocates of nuclear for at least a partial solution to the energy problem.

This is an interesting object lesson, and if science education for the masses could be based on this model, what a fine world it would be. But the trouble is that nuclear power is only one of hundreds of complex technological issues, and none of us can spend a semester on each. Also, there are not enough Jeremy Bernsteins to go



SAMUEL C. FLORMAN, a civil engineer, is author of *Engineering and the Liberal Arts*, *The Existential Pleasures of Engineering*, and *Blaming Technology*. Late last year Mr. Florman was honored

by the American Society of Mechanical Engineers with its Ralph Coats Roe Medal.

around—to say nothing of traveling experts and Princeton science majors.

Learning versus Knowledge

The trouble with letting a few make decisions for the many is that the many might, if they knew more, want to do something different. There is a further concern, however. Some people fear the coming of “a new kind of Dark Age—a time when small cadres of specialists will control knowledge and thus control the decision-making process.” (The quote is from *Higher Learning in the Nation's Service*, cited approvingly on the *New York Times* op-ed page by the president of Cornell University.)

I do not fear the coming of a sinister technocratic cabal, mainly because on consequential issues the technicians invariably give conflicting advice, and the politicians end up making the decisions whether they want to or not. (Jimmy Carter complained about this, and Ronald

Reagan certainly will complain if he hasn't already.) Still, it would be nice to think that people could make choices that intimately affect their own lives.

The paradox defies resolution. A wide diffusion of knowledge is good but the uncertainties are awesome, no citizen can be adequately informed, and perplexing technical reports lead to anxiety and erratic political action. As the saying goes, a little knowledge is a dangerous thing.

Ah, but this is not the saying, at least as Alexander Pope coined it. Pope spoke not of knowledge but of *learning*:

*A little learning is a dangerous thing;
Drink deep, or taste not the Pierian spring:
There shallow draughts intoxicate the brain,
And drinking largely sobers us again.*

Perhaps the semantic difference between “learning” and “knowledge” can give us a helpful clue. Learning is knowledge ac-

quired by systematic study, and a little of that—a few undigested facts—can indeed “intoxicate the brain.” Knowledge in the broad sense, however, implies understanding, discernment, and judgment, and no amount of this, however small, can be a dangerous thing. A knowledgeable public will not expect to resolve each technical issue by analyzing evidence, but will seek to establish a fruitful relationship with its experts—and its politicians—a combination of trust and suspicion, respect and obstinance, calculated to best translate social objectives into technical decisions. Science educators and science journalists will have to explore uncharted realms to responsibly assist this process.

I believe that we have been too simplistic in our assumptions about science education and the public. While I'm rethinking the big picture, however, and resigning myself to reliance upon experts, I plan to keep asking my dentist what they're discovering—if anything—about silver fillings. □

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Genetic Engineering: Life as a Plaything

IN a process almost as old as the earth, a huge panoply of organisms has evolved. The process has been one of chance and selection, and the star player has been the gene. For 3 billion years, natural changes in the number, structure, and organization of genes have determined the course of evolution.

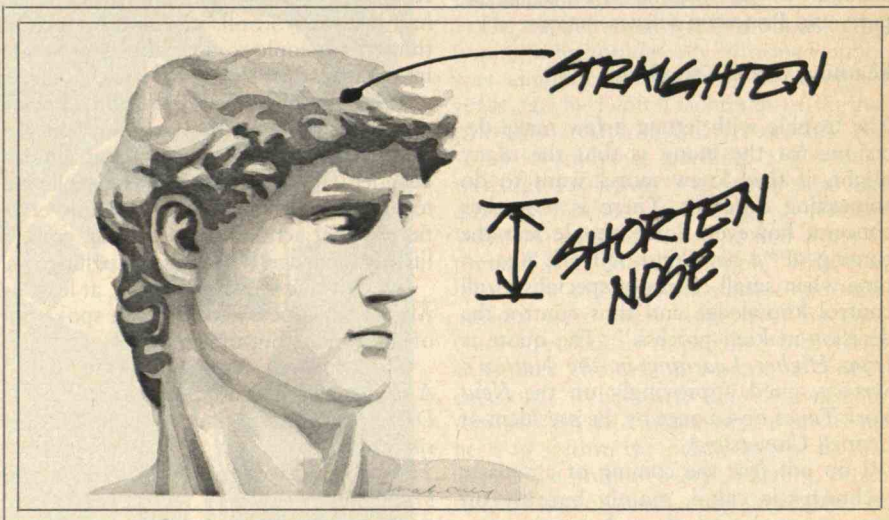
We have now come to the end of that familiar pathway. Genetics—the science of heredity—has unlocked the code book of life, and the long-hidden strategies of evolution are revealing themselves. We now possess the ability to manipulate genes, and we can direct the future course of evolution. We can reassemble old genes and devise new ones. We can plan, and with computer simulation ultimately anticipate, the future forms and paths of life. Mutation and natural selection will continue, of course. But henceforth, the old ways of evolution will be dwarfed by the role of purposeful human intelligence. In the hands of the genetic engineer, life forms could become extraordinary Tinkertoys and life itself just another design problem.

Genetic engineering is a whole new technology. To view it as merely another technological development may make sense for those who invest in its commercial exploitation. But such a view is myopic for anyone concerned with the future of humanity. I want to consider three major areas of concern that will surely arise from this new technology. The first is the transformation of the science of biology itself. The development of molecular genetics is a transition as profound for biology as the development of quantum theory was for physics and chemistry. Until recently, biology was essentially an analytical science, in which researchers undertook the dissection of nature as observed. Genetic engineering now furnishes us with the ability to design and invent living organisms as well as to observe and analyze their function. If we consider the significance of synthesis to the science of chemistry, we can perhaps envision the importance of this development for the science of biology.

A New Biology

The new techniques open the door to a de-

ROBERT SINSHEIMER, a molecular biologist, is chancellor of the University of California at Santa Cruz.



tailed understanding of the form and organization of genetic structures in higher organisms, of the control of gene expression, and of the processes of cellular differentiation. Out of such knowledge will come a new biology that gives us the means to intervene in life processes at the most basic possible level.

The impact of this new biology on the practical and technical arts—the second area of development—will be profound. With this technology, human ingenuity could design agricultural crops that thrive in arid zones or brackish waters, that provide better human nutrition, that resist disease and pests. Human-designed crops, adapted to the needs of efficient agricultural technology, could leap ahead of their natural parasites and predators.

In chemistry, microorganisms could be programmed to carry out the complex organic synthesis of new pharmaceuticals, pesticides, and chemical catalysts. Other organisms could be programmed to degrade chemical compounds and reduce environmental pollution. In animal husbandry, the prospects seem equally bright for designing disease-resistant, fast-growing, nutritious animal forms. In medicine, we envision the synthesis of antibiotics, hormones, vaccines, and other complex pharmaceuticals. But these achievements, almost certainly feasible, will pale before the potential latent in the deeper understanding of biology.

Control over gene expression will provide a whole new array of therapies for genetic disorders. And that introduces the third domain of consequence and the most

profound. With the decline of infectious diseases, genetic disorders are now increasingly the source of ill health. Diabetes, cystic fibrosis, sickle-cell anemia, and Tay-Sachs disease all stem from well-recognized genetic defects. The possibilities of human gene therapy—replacing the “bad” gene with the “good”—are extraordinary. (For another viewpoint, see “Gene Therapy: Will It Work?” page 82.)

The Darker Side

It is not hard to sense the excitement, the challenge, the promise in all these ventures. But is there a catch? Is there a darker side to this vision as we have come to see in other new technologies? Some of us believe there may be—that life is not just another design problem, that life is different from nonlife. Just as nature stumbled upon life some 3 billion years ago and unwittingly began the whole pageant of evolution, so too the new creators may find that living organisms have a destiny of their own. They may find that genetic engineering has consequences far beyond those of conventional engineering.

As we become increasingly confident that this technology can, in fact, be achieved, there are a few major questions to be asked: Is it safe, is it wise, is it moral?

First, is it safe? If we can keep the developments open to public scrutiny, then I believe in the short-term it probably is. We can monitor the hazards of any new

product we introduce into the biosphere and can probably cope with any immediate, untoward consequence.

For the long-term, however, I am considerably less sure. Life has evolved on this planet into a delicately balanced, intricate, self-sustaining network. Maintaining this network involves many interactions and equilibria that we understand only dimly. I would suggest that we must take great care, as we replace the creatures and vegetation of earth with human-designed forms, as we reshape the animate world to conform to human will, that we not forget our origins and inadvertently collapse the ecological system in which we have found our niche.

Through intensive study, we have learned of the different pathogens that prey on humans, animals, and major crops. But we have a very limited understanding of the evolutionary factors that led to their existence. We have limited knowledge about the reservoir of potential pathogens—organisms that could be converted by one or two or five mutations from harmless bugs into serious menaces. And thus we cannot really predict whether our genetic tinkering might unwittingly lead to novel and unexpected hazards.

More broadly, is it wise for us to assume responsibility for the structure and cohesion of the animate world? Do we want to engineer the planet so that its function requires the continuous input of human intelligence? Do we want to convert Earth into a giant Skylab?

Life as Our Plaything

What happens to the reverence for life when life is our creation, our plaything? Will we have species with planned obsolescence? Will we have genetic olympics for homing pigeons or racing dogs? Will we have a zoo of reconstructed vanished species—dinosaurs or sabre-toothed tigers—or as-yet unimagined species? Genetic engineering will inevitably change our sense of kinship with all our fellow creatures.

Will the extinction of species mean much when we can create new ones at will? Until now, we have all been the children of nature, the progeny of evolution. But from now on the flora and fauna of Earth will increasingly be our creations, our designs, and thus our responsibility. What will happen to our nature in such a world?

The most profound consequence of this technology is its application to humankind. The impetus to employ genetic engineering on the human race will come, I believe, out of our humanitarian tradition. Genetic engineering will be seen as just another branch of surgery, albeit at the most delicate level. Since we now know that many sources of human misery are genetic in origin, the urge to remedy these defects and even eliminate their transmission to succeeding generations will be irresistible. Thus, these changes will become part of the human genetic inheritance—for better or worse.

Having acquired the technology to provide genetic therapy, will we then be able to draw a line and restrict human genetic experimentation? How will we define a "defect"? And how will we argue against genetic "improvement"? Or should we? Will we even stop to consider the morality of what's being done?

The extent to which our more specifically human qualities—our emotions and intellects, our compassion and conscience—are genetically determined is not yet known. But geneticists cannot escape the dark suspicion that more is written in our genes than we like to think.

What will happen if we tamper with our physical or mental traits, given the complexity of human development and behavior? Such banal qualities as height or weight can surely affect one's identity, and good health has its own concomitants. How many of our greatest artistic works have been produced by the afflicted or the neurotic?

I suspect human genetic engineering is repugnant to many people because they think its purpose is to impose an identity upon a descendant, to replace the sport of Nature with models of human fancy.

In some sense, education is an attempt to impose an identity. An educational system demands adherence to values of attention, concentration, delayed gratification, and so on. Mere literacy, while enlarging freedom by opening new worlds of knowledge, destroys the freedom of innocence. Yet clearly we have long decided that the virtues of literacy outweigh any drawbacks. Universal literacy is regarded as good and mandated in most societies. Might there be similar genetic characteristics that we would come to regard as a universal good?

(Continued on page 70)

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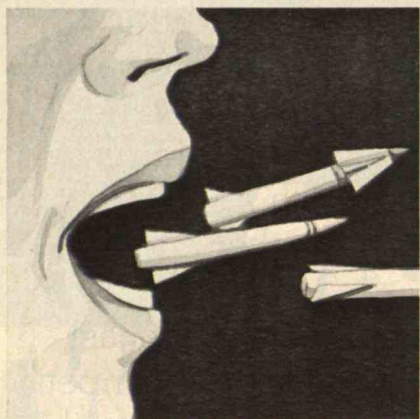
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Nuclear Insularity

Cult of the Atom

by Daniel Ford

Simon and Shuster, 1982

Nukespeak

by Stephen Hilgartner, et al.

Sierra Club Books, 1982

Reviewed by Irvin C. Bupp

Abuse of power and neglect of responsibility are serious accusations. When levied against public officials, these charges are particularly frightening, for they suggest crimes that broadly threaten society.

Congress created the Atomic Energy Commission (AEC) in 1947 to develop and build nuclear explosives, and to develop—but, in general, not to build—machines that use atomic energy for nonmilitary purposes. During the 1950s and 1960s, the agency carried out the first assignment effectively. Less than a decade after the AEC was created, it had rebuilt the decrepit factories it inherited from the U.S. Army into a nationwide industrial enterprise capable of producing thousands of sophisticated nuclear explosives each year.

The AEC's achievements in nonmilitary research and development are more dubious. Indeed, many observers believe that the agency's performance was an utter failure. Daniel Ford, author of *Cult of the Atom*, and Stephen Hilgartner, Richard C. Bell, and Rory O'Connor, authors of *Nukespeak*, are among such critics. They explicitly question both the competence and the motivation of the officials who

managed the AEC during the 25-odd years of its existence. Implicitly they go further. Both books indict the executives of the AEC and its successor agencies, the Department of Energy and the Nuclear Regulatory Commission, for systematically, continuously, and deliberately abusing their power and neglecting their responsibility.

The catalogue of charges is long. In part, government officials are alleged to have:

- Misled local citizens and the public about the hazards of fallout from nuclear-weapons tests.

- Suppressed the results of research about the hazards of nuclear power plants.

- Fired scientists, technicians, and administrators who questioned official doctrine about nuclear safety.

- Conducted public-relations campaigns to promote this doctrine and support a host of dangerous and/or useless official projects.

- Invented euphemisms to deliberately mislead and confuse the public.

- Organized a regulatory system staffed by technically incompetent people, who were ordered to delegate authority to those whose behavior they were supposed to regulate.

- Failed to develop an accounting system to keep accurate records of thousands of kilograms of weapons-grade uranium and plutonium.

- Failed to recruit a technical staff with the competence to do original engineering work on reactor safety.

- Misrepresented an in-house study of reactor safety as the work of independent, outside experts.

- Distorted the results of the same study in a lavishly promoted "executive summary."

- Adopted a reactor licensing policy that, in effect, denied licenses only to specific plants that were "uniquely" unsafe.

- Ignored the problem of radioactive-waste disposal for civilian nuclear power plants.

- Mismanaged hundreds of millions of gallons of dangerous wastes from the manufacture of nuclear weapons.

Daniel Ford was an effective antinuclear activist during the 1970s. However, he has maintained privately as well as publicly that his opposition to nuclear power is pragmatic and empirical. He claims to see no absolute flaw in it. In-

stead, he merely regards it as an extraordinarily complex technology with enormous potential dangers that demand the highest order of scientific, technical, and managerial skills if its promised benefits are to be realized. For him and his associates at the Union of Concerned Scientists, the central issue in the development of nuclear power has been the vast chasm separating the requirements of the technology from the competence of those who have purported to control it.

Many of the latter have commonly responded by questioning, in turn, the motives of members of the Union of Concerned Scientists and other pragmatic critics of nuclear power. Supporters of nuclear power dismiss the allegations as camouflage for absolute "antinuclear" sentiment and purpose.

This is, of course, both unknowable and irrelevant. Whether Daniel Ford is ultimately motivated "to stop nuclear power" is as much beside the point as Ford's own gratuitous speculation that one-time AEC head Glenn T. Seaborg was driven to re-power industrial society with the element—plutonium—he himself discovered as a young scientist.

The real questions are whether AEC officials did abuse their power and neglect their responsibilities, and if so, whether there are generalizable reasons why they were able to do so. Ford provides a compelling answer to the first question, a powerful accusation consistent with the accounts of others such as the Kemeny Commission. In the absence of intelligent response from those he accuses, his account is likely to harden into society's summary judgment about their behavior.

What Ford has not attempted is to develop a *structural* explanation for what went wrong. What precisely was it about the pattern of incentives, sanctions, information flow, and authority within and among the institutions that tried to develop nonmilitary nuclear technology that produced such an unsatisfactory outcome? Within this decade, the nuclear industry will probably produce one-fifth of the nation's electricity. Obviously, it is important to all of us that society understands why these abuses occurred and what can be done to avoid them in the future.

If Ford's failure to pursue these lines is a disappointment, so, too, is the book's style. Ford is a gifted storyteller with a sharp, sardonic wit. Even though I was

familiar with much of the substance of *Cult of the Atom* before reading it, I had anticipated the entertainment of watching a master skewer his opponents. Oddly, little of Ford's eye and ear for the truly ridiculous comes through in his rather pedestrian, unduly technical prose.

There are a few exceptions. For example, Ford deftly indicts engineers of the General Electric Co. for proposing a safety design that would "deliberately [worsen] an accident in order to control it. . . . It was as if a doctor decided to induce pneumonia so that somebody's common cold could be cured with antibiotics."

Linguistic Cover-Up

In contrast, *Nukespeak* is a series of essays of widely varying length loosely knit together by three themes. The first and dominant theme is the authors' profound distaste and distrust for nuclear technology. The authors make no pretense here of presenting a pragmatic criticism of nuclear power and weaponry. They cast all nuclear technology as the unfortunate, if not potentially apocalyptic, outcome of an essentially amoral scientific quest. In counterpoint is an apparently equal distrust of science, or at least scientists.

In the book's first chapter, turn-of-the-century atomic researchers are made to seem thoroughly foolish. Interestingly, the authors do this by citing commentary by journalists (plus H.G. Wells) about the work of these scientists. One fact that the authors, all journalists themselves, firmly establish is that such popularizers have distorted nuclear science and technology since Roentgen announced his discovery of x-rays on January 6, 1896.

Unfortunately, these first two themes overwhelm the third—the most interesting and the advertised heart of the book—that "the language we use has important influences on our thinking." This important and correct assertion is the very first sentence of the book, which is dedicated to George Orwell. (The title is a takeoff from the term "Newspeak" he coined in 1984.) The authors contend that nuclear scientists, technicians, and administrators have developed a language—"Nukespeak"—that, by encoding their own beliefs and assumptions, influences public understanding of nuclear technology.

The cuteness of the slogan aside, this should be a productive hypothesis. The problem, of course, is to identify Nuke-

speak with some precision so that we can know when it is being used, and then to show how it has influenced understanding of nuclear power and, presumably, behavior. But the authors make little progress toward either end.

They use italics throughout the text to highlight Nukespeak words and phrases, a typographical device that quickly becomes an annoying intrusion. For example, we read: "The Acheson-Lilienthal report proposed to classify nuclear activities into two categories, *safe* and *dangerous*, and to require that all *dangerous activities*—those which allowed access to material that could be used in weapons—be carried out exclusively by the international Atomic Development Authority." Later the authors quote a statement by the president of an AEC contractor company: "We would, however, make every effort to find him a *suitable opening* in this organization, or *allow* him to look beyond the company."

The book also contains an index of Nukespeak words, such as "nuclear umbrellas," "retroactive secrecy," "slow-motion countercity war," "clean bomb," "sunshine units," "megadeaths," "peaceful nuclear device," "covert diversion" (theft), and so on. But "safe," "dangerous activities," "allow"? There is some serious mixing of apples and oranges going on here.

Plutonium is, as the authors note, no more a "potential nuclear explosive" than TNT is a potential chemical explosive. But they cast their linguistic net so wide that the variety of the catch obscures rather than sustains their basic argument. For example, the authors devote considerable space to describing the highly compartmentalized operations of the army's Manhattan Project to develop an atomic bomb during World War II. The authors discover that the project's managers went to extraordinary lengths to conceal its existence and purpose from insiders as

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well as the public. For example, the word "tuballoy" was used as the code name for uranium.

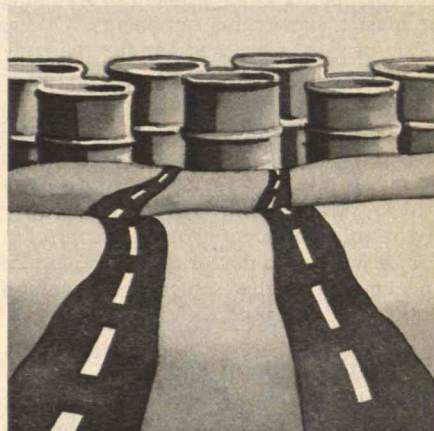
But the admittedly elaborate secrecy surrounding the Manhattan Project was not exactly pointless—there really were spies. And the authors know quite well that some secrets are worth keeping. By confusing the probably necessary "security" (pardon the Nukespeak) measures of the Manhattan Project with the undoubted excesses of the civilian AEC, the authors miss an opportunity to contribute to our understanding of a real moral problem.

Clearly, language sometimes allowed people to behave in ways society would almost certainly have judged unacceptable. The case seems strongest when the authors describe the AEC's public-relations campaigns in support of the atmospheric

weapons tests in Nevada of the 1950s. This use of language was, and is, an independent threat to society's values, perhaps a far larger threat than that of nuclear technology itself. If the authors of *Nukespeak* had adhered to this theme, cataloging the attempts by developers of nuclear power and weapons to pervert language for narrow and controversial ends, the contribution would have been both novel and significant. But by drifting far from this advertised objective, the authors end up preaching only to the already converted about the dangers of nuclear technology. □

Irvin C. Bupp is professor of business administration at the Harvard Business School and coauthor of Energy Future: Report of the Energy Project at the Harvard Business School (Random House, 1979).

Oil Market Shuffle



The Oil Market in the 1980s
by Dimitri Aperjis
Ballinger, 1982

Reviewed by James L. Paddock

The world oil market is a forecaster's nightmare—seldom have so many knowledgeable observers been so wrong so often. Prior to 1973, few foresaw the magnitude of the price jump that would result when oil supplies were disrupted, or predicted the years of relative stability that followed. The Iranian revolution brought a similar surprise. When the Iran-Iraq war began in the fall of 1980, again a major price shock seemed at hand. Experts still are arguing about why it did not occur.

In *The Oil Market in the 1980s*, Dimitri Aperjis makes a valiant attempt to combine economic and political influences likely to determine the oil market's course through 1990. Confounding as these factors are, he develops a quantifiable model that allows him to simulate scenarios of the path the oil markets may take through the decade. Whether or not one agrees with his conclusions, his approach and qualitative insights are critical reading for oil-market analysts.

However, political factors are always difficult to link with economic analyses. The first step toward unraveling these various effects on the world's economies is to determine the relationships among the gross national product (GNP), oil supply and demand, and oil price. Like most oil-market analysts, Dr. Aperjis treats these relationships too lightly, particularly the tough problem of simultaneously de-

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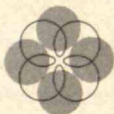
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termining GNP and oil prices.

Two roads lead into that swamp (none, so far, has led out). The first is to specify GNP growth; then, from estimating the energy needed to sustain that GNP, to find the demand for oil; and finally to compare this demand with estimates of potential oil supply. The relationship between supply and demand determines whether price paths will be low, medium, or high.

Dr. Aperjis and a host of others follow this first road. Coupling these three price situations with hypothetical political developments, he forecasts scenarios for oil-market behavior.

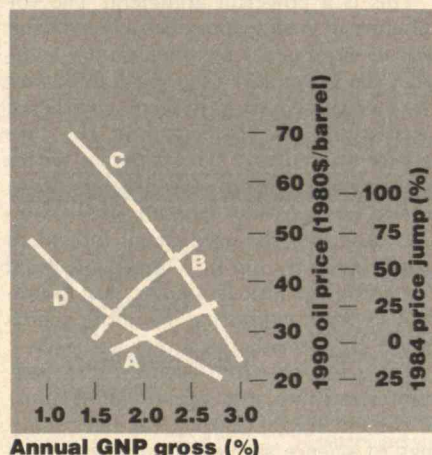
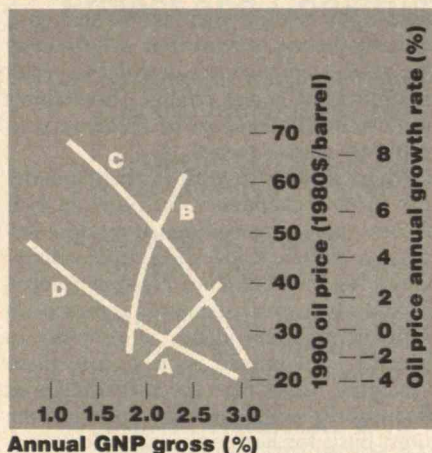
Followers of the second road start with varying estimates of oil prices (again, usually low, medium, and high) and then determine oil demand based on how consumers and industry are expected to respond to the prices. The likelihood of each price scenario can be judged when compared with potential oil supply.

But both roads lead directly into the swamp of ignorance about the effects of oil prices and GNP growth on each other, and thus on oil demand and supply. Political uncertainties and possible "cartel" behavior add to the murk and gloom. Thus, forecasters cannot really tell us whether oil prices will follow a low, medium, or high path.

The Swamp's Boundaries

To account for basic economic theory yet allow for political uncertainty in the oil market, Professor Henry D. Jacoby of M.I.T. and I have developed a different approach to exploring the relationship between future world oil prices and economic growth. Rather than seeking a "right" answer—or single-path forecast—we attempt to identify a range of feasible outcomes. We select a set of possible combinations of oil prices and world economic conditions during the 1980s and then use analytical models and our own judgment to determine which combinations are unlikely to occur. We reject those improbable combinations. The window of "not-unlikely" combinations that remains shows how the world oil market may develop. We then take into account other possible constraints, including the hypothetical behavior of OPEC leaders.

The results appear in the two drawings. If we use the United States as an example, the top figure shows which combinations



Two windows showing the "not-unlikely" combinations of oil price and average annual GNP growth until 1990. The top chart shows the outcome assuming that prices increase smoothly in the 1980s. The bottom chart shows the outcome if a sudden price shock occurs in 1984.

The vertical axes show the rates of growth of oil prices that yield various 1990 oil prices. The combinations where demand exceeds supply—combinations that are deemed unlikely—are below line A. Combinations of very high oil prices and very low economic growth—points above line B—are unlikely because the Saudis will maintain enough oil production to pay for their imports.

There is a limit to the GNP that can be sustained for each oil price, shown by line C. Since oil prices will not dampen GNP growth indefinitely, there is also a minimum probable GNP associated with each oil price, represented by line D.

of oil prices and GNP are not unlikely in 1990 assuming that a sudden price shock does not occur. The lower one shows not-unlikely combinations if a sudden shock should occur in 1984.

OPEC core countries, particularly Saudi Arabia, control a large portion of the world's capacity for producing oil. Thus, a key assumption determining the level of supply is that Saudi Arabia will produce no more than 8.5 million barrels a day (mbd), the limit set by Saudi national policy. If the Saudis produce more than that—say 12.5 mbd, the capacity they are reportedly gearing up for—then the increased oil supplies would make possible higher rates of economic activity and lower price increases.

There is also a probable lower limit on Saudi production, set by the Saudis' need for foreign currency to pay for goods they import. This means that they will produce enough oil so that the combinations of extremely high oil prices and extremely low economic growth are unlikely to occur.

Finally, the effect of energy prices on the U.S. economy makes certain combinations of oil prices and GNP unlikely. That is, for any oil price there are maximum and minimum GNPs. After ruling out all the unlikely combinations of oil prices and GNP growth, we have the window of combinations through which the world is likely to pass in 1990—shown in the top figure.

Of course, this window may change: the bottom figure illustrates the effects if a single, sudden price shock were to occur in 1984. If we assume that oil prices and economic growth will be stable but at very different levels before and after the price hike, another window of not-unlikely combinations appears.

The major difference between the two windows is in the upper range of oil prices that cannot be ruled out. The price is lower in the price-jump scenario because the shock will cause demand to decrease sooner than in the smooth-price case. The important point is that both windows are large, suggesting that forecasts showing specific paths for oil prices should be viewed with great suspicion. □

James L. Paddock is a research associate in the Energy Laboratory and a lecturer in the Sloan School of Management at M.I.T.

Finding the Third Way



The Ecology of Freedom: The Emergence and Dissolution of Hierarchy
Murray Bookchin
Cheshire Books, 1982

Reviewed by Rosalind Williams

For the past 30 years Murray Bookchin has committed himself to articulating a social philosophy that is a "third way," distinct from both Marxist socialism and industrial capitalism. He speaks from a long and venerable tradition of social thought that includes utopian socialists such as the Frenchman Charles Fourier and the Russian anarchist Peter Kropotkin. According to these thinkers, changing ownership of the means of production from capitalists to the state is futile if production remains centralized and bureaucratic. The means themselves must become more human-scaled and dispersed.

Until 1952, Bookchin tells us in *The Ecology of Freedom*, his background and outlook were typically socialist: Russian Jewish immigrant parents, New York City childhood, autoworker and foundryman, union activist during the Depression. But in 1952 he "became acutely conscious of the growing environmental crisis." He changed direction and began advocating decentralization, alternative technologies, communes, and environmentalism.

Far from taking pride in his prophetic insight—although he has every right to—Bookchin laments that "decentralization" and "environmentalism" have become popular slogans no longer understood as expressions of a coherent social

philosophy. Unless they are related to a unifying theory, he fears they will fly away like other trendy causes and fail to result in significant social change. Bookchin's purpose in *The Ecology of Freedom* is to enunciate such a theory.

Where he does so most explicitly, in the first and last chapters of the book, he is at his best, using the findings of modern science as evidence for social philosophy. According to Bookchin, ecology teaches us that the order of nature is based on complex interdependence and "unity in diversity." In human society, too, these principles, rather than the prevailing ones of authority and hierarchy, provide the surest basis for harmonious development.

This is a powerful argument. The vocabulary of ecology provides a convincing way to express, for a contemporary audience, the principles of the social third way that existed long before the term "ecology" was invented in the late nineteenth century. For example, where Kropotkin said that individual freedom had to be based in "community," Bookchin describes the need of all individual organisms to occupy an ecological "niche." The idea is similar, but Bookchin's way of expressing it is more appropriate for a twentieth-century audience.

But if the appeal to ecology is rhetorically irresistible, it is logically dangerous. In the nineteenth century, the latest findings of science seemed to support social Darwinism, which proclaimed that in human society, as in nature, progress is based on tooth-and-claw competition. Although the Darwinist outlook seemed quite convincing at the time, today most thinkers dismiss social Darwinism as a pseudo-scientific means of defending otherwise indefensible economic privilege.

Scientific truth cannot be considered immutable. If we base our political judgments on the latest scientific theories, the next scientific revolution may jerk the rug out from under our feet. In the end, the evidence to support a social philosophy must come from society itself, which is to say human experience—or history.

Bookchin is well aware of this, and therefore in the middle chapters of *The Ecology of Freedom* he sets out to rewrite history. His premise is that tribal peoples who live close to nature spontaneously order their "organic societies" on ecological principles such as the interdependence of living things. The story of human history is the gradual evolution of

such societies away from these nonhierarchical principles to the present state of "civilized" authority and domination.

This enterprise is praiseworthy. Bookchin rescues worlds of the past that are usually submerged in standard narrations of wars and governments: the hidden histories of women, of family life, of informal technologies, of communities. Bookchin rightly argues that retrieving the lost "history of freedom" is a necessary first step in opening up a future of freedom from hierarchy. By doing so we grow aware of past networks of human associations on which we can build.

Making Human Distinctions

But the problem is that Bookchin's effort at historical retrieval is so irretrievably dull. Sympathetic reviewers have called the book his *magnum opus*, and *magnum* it certainly is—too much so. Bookchin claims that the repetition is deliberate, for "it would be arrogant to present finished analyses and recipes." But the real arrogance is to assume that the reader is going to be stimulated by his every musing.

As usual, problems of style reflect those of substance. If the book is dull, the main reason is that Bookchin works with only a few basic ingredients, inflating them far beyond their inherent intellectual value. He tries to puff up an airy soufflé when an unpretentious, well-cooked omelette would be far tastier.

The soufflé begins to sink as early as the second chapter, when Bookchin keeps telling us how wonderful are the Hopi Indians, the Ihalmiut Eskimos, and the like, concluding with a poignant, nostalgic elegy to the lost Eden of Neolithic times when everyone lived in harmony with nature. Even a sympathetic reader must wonder if Bookchin is not idealizing his collective "organic" hero. In the case of Neolithic social life, any description must be highly, even wildly, conjectural. Bookchin conveniently dismisses any troubling evidence concerning more recent "organic societies." He says that if these tribes seem tainted by the sins of hierarchy or domination, this "usually can be explained by unsettling technological changes, invasions, problems of dealing with a particularly difficult environment, and, above all, by contacts with whites."

Bookchin doesn't have to be so defensive. His vision of a better social future does not depend on proving that Neolithic

people or American Indians are perfect. All he needs to say is that "primitive humans" are neither beast nor angel: that the major difference between these societies and ours is that individuals identify their existence far more strongly with that of the group, and that we need to regain awareness of our solidarity with nature rather than clinging to illusions of hyperindividualism and autonomy.

The obvious question is whether such a sense of solidarity can be rekindled in modern societies, which are so much wealthier in material goods, more complicated in technologies, and larger in population. Bookchin argues that the origins of hierarchy are not material but mental—that people's consciousness of differences in age and sex slowly became rigid and institutionalized. But if hierarchies emerged so far back in the evolution of human society, aren't they, too, naturally human? Indeed, there can be no moral sense at all, and therefore no society, without creating levels of values, meanings, priorities. Even to maintain that freedom is better than authority is to insist on hierarchy. The task is to establish truly human hierarchies, not to dream of a consciousness without levels.

As far as Bookchin can see, any justification for hierarchy is a rationalization dreamed up by a "cunning elite." But many strong human desires and loyalties, such as urbanization and nationalism, contribute to the evolution away from "organic societies." History teaches the ambiguity of human motives, their tangled and chequered quality. However, Bookchin doesn't like ambiguity. In fact, he is not really writing history at all, but a form of theology in which the forces of light contend with those of darkness, where good "organic societies" fall down to become bad "civilized" ones, with Eden at one end of time and utopia at the other.

I am sorry to be so ungrateful. Bookchin deserves to be taken seriously because the third way deserves to be. But regrettably, a book like *The Ecology of Freedom* will be praised by the usual people and derided by the rest. It will cause flooding in the usual places instead of becoming part of the mainstream of political discussion, where it belongs. □

Rosalind Williams, an historian, is author of *Dream Worlds: Mass Consumption in Late Nineteenth-Century France* (University of California Press, 1982).

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I began my career with AT&T climbing poles during a high school vacation. Now, that business I joined 43 years ago is facing its greatest challenge: the agreement with the Justice Department requiring us to divest the 22 Bell System telephone companies by early 1984.

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We provide a service critical to business and commerce, to government and education, to national defense, to individuals in their daily lives. We are embedded in the very life of the nation.

We're adapting our business to what the public expects.

I'd be less than truthful if I didn't say we have mixed feelings about breaking up a 100-year-old institution which has served the nation very well. On the other hand, we cannot live outside our times. And clearly, the times have

changed. The American people really don't want monopoly, no matter how well regulated. They want competition and the choices that brings.

Technology has changed as well. Not too long ago, data processing was one thing, communications another. That's no longer true. As a result, many companies here and abroad have the technical know-how as well as the marketing resources to deliver high-quality communications products, services, and systems. Thus, the Bell System could not expect to operate and do business as it always has.

Never underestimate the resourcefulness and dedication of telephone people to figure out how to reach a goal.



UTURE, NOT DEMOLITION"

Chairman of the Board, AT&T

The task of divesting is vastly complicated. But we have the human talent. We have the engineering and scientific resources. And we have our pride.

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Restructured by a Consent Decree with the Justice Department, the new AT&T will be able to develop and apply its technologies to the fullest.

In considering the Consent Decree proposal, we thought long and hard about whether the new structure would imperil our ability to serve. And of course we never would have accepted any terms that automatically would have degraded the quality of service to the nation. The Decree gives us the opportunity to build even better communications services and systems because it removes the arbitrary constraints which have limited us in the applications of our technologies.

We're eager to bring the benefits of all our innovations to the consumer in the competitive Information Age marketplace.

Both AT&T and the local phone companies have a bright future.

We're at the heart of the fastest growing, most promising industry in the country. The new AT&T—with its long-distance network and its new subsidiary, American Bell, plus Western Electric and Bell Labs—is in league with the future.

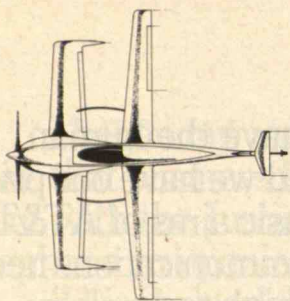
The telephone companies, which already provide a local communications system reaching virtually every home and business, are enhancing the quality and capability of their local lines so they can handle total information services: voice, video, data, even the new cellular mobile phone services. We are pledged to divest these companies in sound financial shape. We will keep that pledge.

This industry is where the opportunities and the excitement are.

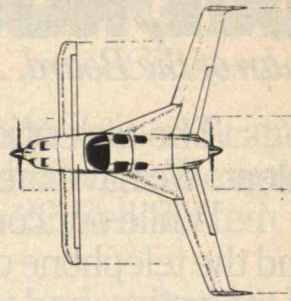
If we have a truly competitive communications marketplace, with regulation only where it is needed, I believe AT&T and the divested telephone companies have a significant and constructive role to play in revitalizing the American economy and in maintaining and enhancing US technological leadership in communications.

The Bell System as we now know it will be no more. We will divest. But we are not demolishing the promise of tomorrow. That promise is alive and well. Bell System people are ready for new directions.





Homebuilt Airplanes:



The Sky's the Limit

BY ELAINE DE MAN

Today's "do-it-yourself" airplanes, often featuring high-tech designs and materials, are taking aviation enthusiasts to new heights in flight.

IN 1903, Wilbur and Orville Wright packed up the parts to their "Flyer" and shipped them from Dayton, Ohio, to North Carolina for their historic flight. In 1910, Alberto Santos-Dumont, who made the first powered flight in Europe, published the plans to his high-winged monoplane, *Demoiselle*, in *Popular Mechanics*. By 1919, the E.B. Heath Aerial Vehicle Co. in Chicago was selling kits for everything from hang gliders to flying boats. Kits and plans for homebuilt airplanes have been available ever since. Except for a slight lull after World War I when surplus military airplanes were available at unbeatable prices, and the period from 1938 to 1946 when homebuilt airplanes were outlawed, the market has grown by leaps and bounds.

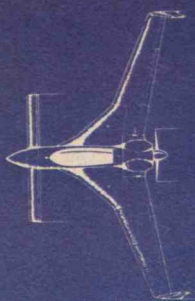
Today there is a homebuilt airplane for almost every pocketbook and certainly every fantasy. Would-be barnstormers can reminisce about days gone by in a Baby Great Lakes or a Marquart Charger—classic biplanes made with wood and steel tube covered with fabric, generally requiring years of devoted effort to build. Nostalgic veterans of World War II can sink their life savings into reconstructing a Corsair or P-51 Mustang, and after many months of riveting and welding they can rocket through the sky in their personal warbird. The Rolls Royce set can flip-flop through the air in the Christen Eagle, a plane

that flies as well upside down as right side up. The Eagle is built from a kit so complete that each package in the crate has a single-edged razor blade taped to the outside.

Homebuilders seeking the latest in technology can choose one of the new "plastic" airplanes. Sophisticated yet easy to build, these futuristic-looking planes are often designed with the help of computers and incorporate advanced aeronautical features. And those wanting to get back to basics can putter through the sky in an "ultralight." Almost primitive in design and function, these craft owe their very existence to advances in materials science. Helicopters, gyrocopters, amphibious airplanes, and sailplanes can all be built at home. Homebuilts carry labels such as "The Freedom Machine" and "The World's Most Efficient Airplane." Some advertise "going straight up," while one kit manufacturer simply commands "do it!"

Rich Tradition, New Technology

The public often looks upon people who build their own airplanes as slightly eccentric tinkerers. But today's homebuilders can draw not only from lessons learned by aviation pioneers, but also on computer-generated designs, space-age materials and construc-



Burt Rutan uses a "canard," the small front wing, on all the airplanes he designs. The canard prevents the plane from stalling, or losing lift, which is a major cause of fatal crashes in conventional aircraft.



This VariEze also has vertical "winglets" and a rear-mounted engine and propeller, aeronautical advances that boost the airplane's efficiency.



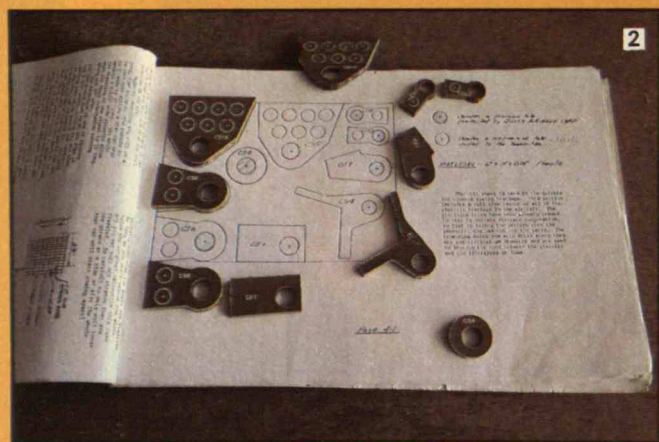
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1 The Quickie is so aerodynamically clean that it cruises over 100 miles per hour on less than a gallon of gas.

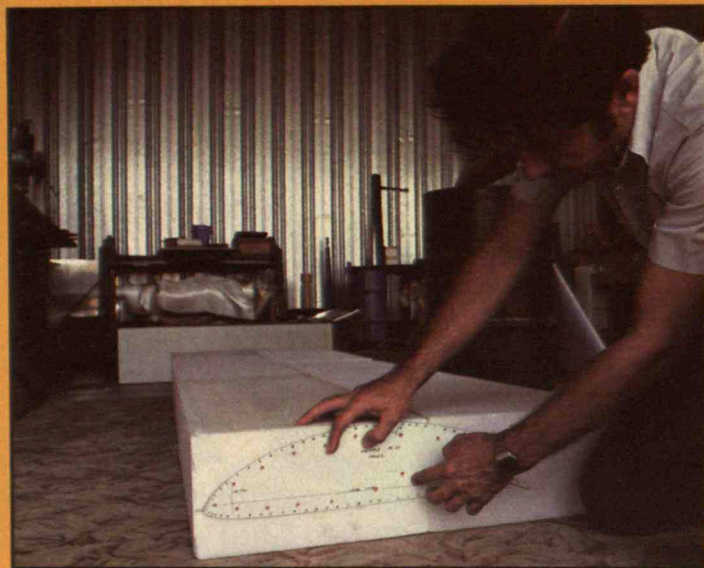
The plane's lightweight structure resists bending and breaking, and a kit with detailed instructions **2** makes it easy to build.

3 and **4** Three types of foam are used to form component "cores." These are carved by tracing templates attached to

both ends of a foam block with a hot wire. The cores are then covered with layers of fiberglass laminated in place with epoxy.



2



tion techniques, and the knowledge of a growing list of aeronautical engineers who are using the home-built movement to realize the full potential of powered flight. At the head of this impressive list of engineering talent is 39-year-old Burt Rutan.

Almost singlehandedly, Rutan has raised the pitch of aviation excitement to levels reminiscent of its earliest days. Aircraft enthusiasts the world over look to the Rutan Aircraft Factory, located at the Mojave Airport in California's Mojave Desert, for new airplanes that roll out like clockwork. Each design seems a little more startling than the last: the VariViggen in 1974, the VariEze in 1975, the Quickie in 1977, the Defiant in 1978, the Long-EZ in 1979, the Amsoil Rutan Racer in 1981, the Grizzly in 1982, and most recently, the Solitaire. Most of these were designed specifically for homebuilders, and with them Rutan ushered in a new era of fast, efficient, safe, and easy-to-build airplanes.

Rather than modify existing designs to meet desired performance criteria, Rutan starts from scratch with a list of characteristics he wants the plane to have. The Amsoil Rutan Racer, for example, was designed not only to go fast but also to conform to strict requirements for racing biplanes. The Racer, designed for and built by Dan Mortensen of Superior, Wisc., now holds the world speed records for a

piston-powered airplane weighing 500 to 1,000 kilograms (roughly 1,100 to 2,200 pounds) over a 3-kilometer straight course (234.64 miles per hour) and a 100-kilometer closed course (233.3 miles per hour).

The Grizzly, a four-place "bushplane" designed for flying into backwoods areas, has two sets of forward-swept wings interconnected with braces that also serve as fuel tanks. Each wing has an extendable flap that can increase the total wing area by 45 square feet. When fully extended, the flaps allow an otherwise high-speed airplane to land in a very short distance. The Solitaire, Rutan's self-launching sailplane equipped with a retractable propellor and very efficient airfoils, won the Soaring Society of America's design competition last summer. The list goes on and on.

Rutan and his staff rely heavily on computer-assisted design systems, using nine Apple computers and a Hewlett-Packard Plotter. "The computer," says Rutan, "is used to analyze and optimize the performance of a given configuration and modifications of that configuration. It's used to develop the shape of the airplane, to plot and mathematically define the shape of a fuselage or a wing, to reduce flight test data, to do structural design . . . everything. In general, it does the monotonous cranking of numbers



3



4

5 The Glasair, designed by Tom Hamilton, is built merely by assembling the factory-produced parts like a model airplane. It can travel 220 miles per hour, thanks to its mirror-smooth finish and the perfect computer-generated "conic curves" of the fuselage.



5

fast enough to allow you to do many integrations and arrive at the optimal design."

Each of Rutan's planes is unique in function and performance but all bear the hallmark of a Rutan design: the canard, an odd little wing sprouting from the nose of the plane. In some designs the canard has evolved into the full status of a second, or tandem, wing.

The canard was actually a design feature of the earliest Wright Flyers, and during World War II several aircraft manufacturers experimented with canards. One of the most promising was a Japanese bomber interceptor called the Shinden. Rutan, however, was the first to successfully use the canard in general aviation in his first homebuilt design, the VariViggen. "The 'loaded' canard configuration that we use [meaning the canard provides some lift] is different from that applied by the Wright brothers or Curtiss with the Ascender, or the Shinden or other earlier examples," says Rutan. "But why it wasn't used a lot more in the past—I really don't know."

The advantage of Rutan's canard is that it prevents stalling. In conventional aircraft, if the angle between the wing and relative wind exceeds a critical limit, the air no longer flows smoothly over the top of the wing. The turbulence generated on the top of the wing causes the wing to lose lift, or stall, and the plane

starts to fall. If the plane is weighted correctly, it will dive, nose-first, toward the ground. As the plane picks up speed, airflow over the wing increases. Sufficient lift is created for the plane to start climbing again—assuming the plane stalled at a high-enough altitude. But sometimes a plane will start to spin as it falls, and unless the pilot makes appropriate maneuvers the result is disaster.

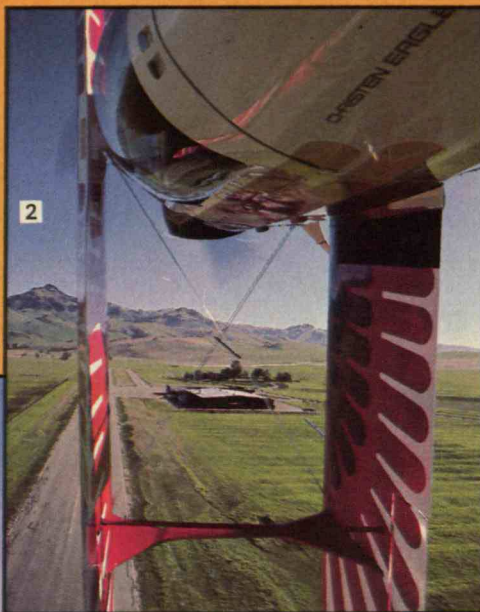
In Rutan's planes, the small forward wing stalls at a lower angle of attack than the main wing. So if the canard loses lift, the plane gently nods forward and keeps on flying; the main wing never stalls. Stall-spin accidents are a major cause of fatal crashes, and the National Aeronautics and Space Administration (NASA), which had been studying such accidents, naturally became interested in the claims being made by Rutan. "It was in our interest to examine these unconventional configurations," says NASA scientist Joe Chambers, "to determine their margins of safety, and to provide information for designers who might make use of this concept to lower the stall-spin accident rate."

After two NASA test pilots flew Rutan's VariEze, NASA bought a kit and modified the plane slightly for testing in the wind tunnel at the Langley Research Center in Virginia. The researchers also tested a four-foot model in a spin tunnel—a vertical wind

1 and **2** The Cristen Eagle is made from a kit so builder needs only time and space.

The Eagle flies as well upside down or on its side as it does right side up.

3 "Ultralights," almost primitive in design, owe their success to new lightweight materials.



4 Homebuilt Corsairs allow nostalgic veterans of World War II to take to the air in their personal warbird.

5 The Rutan Amsol Racer, in which the canard has evolved into a second wing, holds several world speed records.

tunnel with a rising column of air. They found it was virtually impossible to make the VariEze stall or spin.

But NASA's testing did reveal one potential flaw in the VariEze design—under certain conditions the plane would rock from side to side. "Our researchers found that by putting a 'cuff' on the leading edge of the wings for the first several inches, the problem disappeared," explains NASA's Keith Henry. "Rutan reacted immediately to that. He put out a notice to all the people who bought kits and suggested they modify their planes that way."

NASA was not accustomed to having its research put to practical use so quickly. "They [homebuilt manufacturers] have the advantage of being small, so they're a little freer to act in some cases," says Henry. "They're more likely to accept our research because they have less of an investment to risk. The larger aviation companies are starting to respond to much of Langley's work as well, but they're in a little different situation. Their airplanes cost more money and they have more overhead and larger production costs. They also have a tougher time with certification of their airplanes." NASA's evaluation program has now branched out beyond Rutan and the VariEze, and NASA has called canard-equipped planes "the airplane of the 1990s."

Rutan has also added other unconventional

modifications to his designs. For example, most planes are designed with the engine and propeller in front to keep the plane weighted correctly. However, it is actually more efficient to push an airplane through the air than to pull it. To capitalize on this, Rutan sometimes moves the engine and propeller to the back of his planes, counterbalancing the weight by moving the cabin forward. The VariViggen, VariEze, and LongEZ all have engines and propellers mounted in the rear.

The Defiant has an engine at both ends, providing single-engine safety in a high-performance twin-engine airplane. The fore-aft placement of the engines eliminates the need for the pilot to make complicated adjustments when one of the engines fails. Even with the loss of an engine on takeoff, fully loaded, the pilot has enough power and stability to complete the climb-out and continue the flight. The Defiant is probably the safest twin-engine airplane yet designed but Rutan owns the only one, since it has not been put into commercial production.

On the Quickie, a single-place airplane designed for the Quickie Aircraft Co., Rutan doubled the function of the canard by also using it as the main landing gear. This required putting the weight well forward, so the Quickie's propeller and engine (a relatively heavy, two-cylinder, 22-horsepower, air-

Today there is a homebuilt airplane for almost every pocketbook and certainly every fantasy.

cooled, industrial model) are in front. The plane is so aerodynamically "clean" that it can cruise over 100 miles in an hour using less than a gallon of gas. The Quickie's unusual appearance has inspired descriptions such as "squashed mosquito" and "flying banana," but the design has already been copied in several other airplanes.

Foam in Flight

Rutan has also led the way in demonstrating the role that new materials can play in aircraft construction. Except for the VariViggen, all Rutan's planes are built almost exclusively with composite structural components. The components consist of a rigid foam core with numerous layers of fiberglass epoxied to each side, providing a structure that resists bending or breaking. These components have almost the same tensile and compressive strength as aluminum components but weigh only two-thirds as much. And whereas self-propagated cracks are characteristic of fatigue in metal airplanes, each layer of fiberglass in a composite component is a separate entity, so a crack in one layer does not necessarily jeopardize the overall structure.

Rutan uses three types of foam in his planes. Low-density styrofoam, which is easy to cut with a hot wire and resistant to "delamination," is used for the wings, rudder, and canard. Urethane foam, which can withstand exposure to airplane fuel, is used extensively in the fuselage and fuel tanks. And polyvinylchloride (PVC) foam, which has great compressive strength, makes up the main supports—or bulkheads—of the fuselage.

The foam-and-fiberglass sandwich also contributes significantly to the ease of construction. An illustrated manual shows step-by-step procedures, similar to a Simplicity dress pattern. For example, to make a wing, templates are cut from masonite or aluminum and nailed to each end of a long block of foam. A stainless steel wire is stretched on a "U" shaped frame and hooked up to an electric current. The wire becomes hot enough to melt its way through the foam. With a person holding each end, the wire is passed over the templates and a wing core is created in one pass. It is then covered with fiberglass, which is laminated in place with epoxy.

An entire VariEze can be built in 1,000 hours and will cost the builder between \$6,000 and \$15,000 to complete. Because it has composite components, the

plane weighs only 570 pounds but can withstand a load factor of 12 times its own weight, or 12 Gs. Conventional aircraft can generally stand little more than 7 Gs. Its aerodynamic qualities and light weight also make the VariEze more fuel efficient than any other airplane in its class. Cruising at 177 miles per hour, it burns a gallon of gas every 35 miles and has a range of 800 miles or more.

Not one to rest on his laurels, Rutan decided that even the VariEze could be improved, and soon he was marketing plans for the Long-EZ—specially developed for efficient, high-speed, long-range traveling for two adults and their baggage. Fuel economy is slightly less than in the VariEze but the Long-EZ's range is much greater: at "economy cruise" it will travel over 2,000 miles on a tank of gas.

"Smooth-skinned fiberglass or plastic airplanes," says NASA's Chambers, "offer the promise of increased aerodynamic performance and less drag than conventional airplanes." Indeed, NASA was able to document, for the first time, natural laminar flow (a very smooth flow of air over the wing, which delays the onset of turbulence and increases efficiency) during wind-tunnel tests with the VariEze.

"The aerodynamic cleanliness came as a bit of a surprise to us and to Burt Rutan," Chambers says. "As a result of that work with the VariEze, we have stimulated a tremendous amount of interest in the general aviation industry in the fact that natural laminar flow is possible using these materials. Some companies now realize that they should be looking more closely at things like composite construction."

In 1982, *Aviation Consumer* magazine called Rutan the "most innovative and successful lightplane designer in the country. His Long-EZ, Defiant, and Quickie have set the pace for homebuilt design. . . . While Cessna, Beech, and Piper tell us why they can't make faster, stronger, safer, and cheaper airplanes, Rutan simply builds them."

Rutan, like other homebuilders, is not subject to the same regulations imposed by the Federal Aviation Administration (FAA) on the producers of factory-built aircraft. Amateur builders are free to design and build any aircraft they want, although they don't have carte blanche to propel just anything into the sky. A homebuilt aircraft, classed by the FAA as "Experimental—amateur built," is checked by a local FAA inspector at various stages of construction and, before it is flown, must be issued an airworthiness certificate.

Structural components made with foam and fiberglass are almost as strong as aluminum but weigh only two-thirds as much.

Homebuilt aircraft actually have a lower accident rate than their factory-built counterparts, based on the number of registered aircraft, according to a 1980 study by *Aviation Consumer*. This is due largely to the greater number of accidents involving factory-built planes that are caused by "pilot error," such as flying into adverse weather. However, many more homebuilt accidents are attributed to the design or the builder, who may have installed parts incorrectly or tried to cut costs by purchasing cut-rate materials. The most common mistake homebuilders make, according to FAA Inspector Winslow Lim, is "poor quality control." For example, when a fatal crash of a VariEze last summer was blamed on structural failure, Rutan sent a team to investigate the wreckage. The members found that the builder had completely omitted an eight-ply layering of fiberglass and epoxy that was the only source of structural integrity for the part that failed.

Ultimately, builders are responsible for their own welfare. If they follow all the manufacturer's directions, use only aircraft-quality materials, adhere to the FAA's inspection program, and fly their airplanes in a safe manner, they can achieve a level of control that pilots of factory-built aircraft can only envy.

The Field Is Taking Off

While Rutan is still clearly leading the field in innovation, his efforts have paved the way for other designers. In the August 1980 issue of *Sport Aviation*, published by the Experimental Aircraft Association (EAA), Tom Hamilton described his new plane—kits soon to be available to the public—the Glasair. Two hundred and twenty miles per hour. Thirty miles per gallon. One thousand hours to build. Homebuilders were soon beating a path to Hamilton's door.

"I never dreamed this plane would ever get to where it has," Hamilton told a recent gathering of EAA'ers. "This whole thing turned out to be a lot more than I bargained for." Hamilton, who was a college student when he started designing the Glasair, went on to found Stoddard-Hamilton Aircraft, now in Arlington, Wash., and has devoted himself to developing and marketing the new plane.

From a distance, the Glasair resembles a conventional, long-wing, two-place tail-dragger. However, the plane has perfect "conic curves" from the front cowling through the canopy to the tail, a design generated using computer technology developed by Boeing. In addition to "pleasing the eye," this design helps increase aerodynamic efficiency. And up close

to the Glasair, an observer notices the sleek finish with no ripples, rumples, or rivets to impede airflow. The mirror-smooth finish is vital to the Glasair's performance and results from its unique construction.

The Glasair is assembled by joining composite shells that are vacuum-molded at the factory. All exterior surfaces are prefinished with a special gel coat that provides the smooth finish and blocks the sun's ultraviolet rays, which can damage the epoxy-fiberglass structure. The builder merely assembles the pieces like a model airplane and touches up the seams. Obtaining the same smooth surface in a VariEze requires hours and hours of sanding and filling—hours not included in the advertised 1,000-hour building time. The fuselage of Rutan's sailplane, Solitaire, will be built from similar preformed shells.

The success of any homebuilt airplane can be measured by the number of kits sold and the number of planes flying. The VariEze and Long-EZ hold the record for total number of airplanes flying—close to 500 combined—but the Glasair may soon catch up. Since March 1981, 340 kits—including everything except an engine, propellor, and instruments and priced at \$12,500—have been delivered and an additional 100 people have reserved a place on the production line. Today, 20 Glasairs are flying.

Though the initial response to the Glasair was overwhelming, Hamilton still wanted the plane to go faster. He now offers a retrofitable, retractable tricycle landing gear (two main wheels and a steerable nose gear) that boosts speed by 12 miles per hour. The retractable gear package is an additional \$3,600.

Of course, innovations in airplane design and technology are not restricted to young designers such as Rutan and Hamilton. Molt Taylor of Longview, Wash., is 70 and something of a rebel in aeronautics, with a 30-year history of breaking conventions. In the late 1950s he spent \$1 million to develop the Aerocar, a flying automobile with removable wings. "We were all ready to produce flying automobiles," says Taylor, "but the government said 'No. We don't want the sky full of flying machines.'"

Taylor has since worked exclusively through the homebuilt movement to market his designs and aircraft modifications. He sells plans for the Coot-A, an amphibious two-seater, and kits for the Mini-Imp, an aluminum and fiberglass single-place airplane. The Mini-Imp uses a technology Taylor developed for the Aerocar: a rear-mounted propellor driven via a long shaft by an engine mounted toward the front.

"Did you ever see a boat with a propellor in the front?" he asks. "Of course not. For a given amount

The canard,
an odd little wing sprouting from the nose,
greatly improves airplane safety.

of work, you can make the airplane go faster by pushing it. But more importantly, putting the propellor in the back stabilizes the airplane. The only reason the propellor was usually in the front was because of what's called torsional vibration. Internal-combustion engines do not deliver their power in a smooth way—it's a series of explosions. If you put a propellor at the end of a long shaft, the engine would 'buck' against the inertia of the propellor and the shaft would break." Taylor solved the problem by using a special type of clutch called the Flexidyne. It contains thousands of tiny steel balls that damp the power pulses of the engine and smooth the rotation of the shaft turning the propellor.

The Lear Fan airplane, he says, "is a direct result of our work with the tail propellor. And it's a far more efficient airplane than has ever been built before." The Lear Fan is built almost entirely with graphite and carbon-fiber composite material. It can travel at 400 miles an hour with a fuel efficiency of 10 miles a gallon while carrying eight passengers plus a crew. It has a rear-mounted propellor powered by two engines located near the middle of the fuselage.

The Lear Fan is one of the first production-line airplanes to take full advantage of the new materials being developed by the plastics industry, but homebuilders are quick to snap them up. The Quickie has an engine mount made of Kevlar. The Rutan Racer has a front wing made of carbon-fiber cloth to support the big engine. And the Grizzly has carbon-fiber cloth in its flaps to make them rigid enough to extend without support on the outer edge.

Another of Taylor's designs, the Micro-Imp, is also breaking new ground—but with an old material. The plane, which made its debut at last summer's EAA "Fly-In" in Oshkosh, Wisc., is constructed of laminated paper reinforced with fiberglass. The various parts of the Micro-Imp are printed full-size on the paper so the builder can cut them out with a linoleum knife and a straight-edge.

As if a paper airplane wasn't radical enough, Taylor also introduced a new "variable-pitch" propellor with the Micro-Imp. Most homebuilts use a fixed-pitch propellor that, mounted directly to the crankshaft, turns at the same speed as the engine. This means the throttle is the only power control. With a variable-pitch propellor, the pilot manually controls the blade angle. This makes the propellor as efficient during takeoff and climbing as during cruising, allowing the engine to operate at its optimal rpm. Taylor's Micro-Prop is a variable-pitch propellor that can twist all the way to reverse. Naturally the plane

can't fly backward, but the pilot could use this feature to back the Micro-Imp into its hangar or parking space, or to slow the plane down on rollout. The complete kit for the Micro-Imp will cost about \$5,000. A two-place version, the Bullet 2100, is almost finished.

Taylor also experiments with power plants, generally the most expensive part of a homebuilt airplane. Standard aircraft engines such as the Continental and Lycoming are most popular, followed closely by converted Volkswagen and other automobile engines. For example, Taylor's quest for a low-cost engine has led him to convert a Kawasaki 900z motorcycle engine for aircraft use. However, the most promising engines for future light aircraft—made with lightweight plastics and other advanced materials—are now being developed by the automobile industry. "These engines are running," says Taylor, "but I've been unable to get my hands on one for an airplane." He's still trying.

At least one homebuilt airplane has failed for lack of a suitable engine, and because it failed so big has become one of the best-known planes in homebuilt history. In the early 1970s Jim Bede, a respected aeronautical engineer who had developed several successful homebuilt planes, announced the BD-5, the first complete "kit" airplane that promised to be fast, inexpensive, and easy to build. Bede started marketing the BD-5 before the design was perfected, but that didn't stop thousands of people from ordering the kits, sincerely believing they would soon be rocketing through the sky. Bede went bankrupt before it ever happened. "One of the problems with the BD-5," says Taylor, "is that they never did get an engine-propellor-shaft installation that worked."

Several builders have managed to overcome this problem on their own. For example, Norm Alumbaugh of Pope Valley, Calif., has built his BD-5 around a highly modified 325-horsepower Mazda rotary engine. He predicts the plane will go 400 to 450 miles per hour, though he hasn't flown it yet at full power. And, engineers at Bede Micro Aviation in San Jose, Calif., have successfully modified a Turbo-Honda engine for use in the BD-5. But thousands of partially completed BD-5s languish. (Bede now designs and sells a "kit" automobile that bears a strong resemblance to a BD-5 on wheels.) However, few homebuilders would begrudge Bede the credit he deserves for recognizing a need in the aircraft marketplace—one that is now being filled by the likes of Burt Rutan, who, incidentally, worked for Bede in the early days of the BD-5.

The next airborne challenge,
a flight around the world without stopping or refueling,
will be met by an airplane with its roots
in the homebuilt movement.

The Next Challenge

Borrowed technology plays a big role in the development of homebuilts—from engines pirated from automobiles to airfoils generated for the space program. Rutan, for example, was the first to use NASA-developed “winglets” when he designed them into the VariEze. The winglets are vertical fins on the ends of the wings that make them perform more efficiently without increasing the wingspan. Researcher Richard Whitcomb developed winglets for use on large subsonic transport planes of the 737 and 707 class. “We don’t design airplanes,” says NASA’s Chambers. “We just work on technology, and it’s available if the aircraft manufacturers want to make use of it.”

The “Rogallo wing,” which evolved into the modern hang glider, was another NASA concept, developed by engineers working on reentry of the Apollo spacecraft. And the “ultralight” movement was launched when John Moody, an electrical engineer living in Wisconsin, added a go-kart engine and propeller to his Icarus II hang glider. He flew this new contraption before the astounded crowds at EAA’s 1976 Fly-In, and never before had flight seemed so accessible.

Ultralights aside, the trend in homebuilt airplanes is toward speed, efficiency, and ease of construction. Low cost is clearly an advantage, though not a necessity. For example, Frank Christensen’s Christen Eagle II costs \$42,000 for the 28 individual kits required to assemble this aristocrat of aviation. The classic biplane design, with its fabric-and-tube construction, is certainly not new to aviation, but the Eagle-kit concept is. “We recognized a need in the marketplace and fit the plane into that slot,” says Christensen. “We’re the aerobatic people.”

Christensen began his career in the semiconductor industry while he was still a student at Stanford University. He “retired” in 1972, at the age of 32, to found Christen Industries in Hollister, Calif. The single-place version of the Christen Eagle climbs at 2,640 feet per minute and can fly straight up for 2,100 feet and upside down for an unlimited length of time. It’s also one of the few light planes that can gain altitude in knife-edge flight—flying on its side.

Each kit comes with its own instruction manual, which is printed by computer when the order is received so the manual will always be up-to-date. The kit is so complete that the builder requires only time and space. “We’ve tried to do with airplanes what Heathkit had done for years in electronics,” Christensen says. “Anyone can build an airplane if they know

how—so let’s teach them and then give them everything they need.”

But Christensen makes his builders no false promises. “The Eagle is about the most complete kit there is,” he tells them. “You don’t make anything. All you do is put it together, and it’ll take you 1,400 hours to do it. Do you know what 1,400 hours is?” he asks. “That’s eight hours on Saturday, eight hours on Sunday, and seven to ten o’clock every weeknight for a year.” Even so, Christen Industries has sold more than 530 Christen Eagle II kits, and more than 125 Eagles are flying.

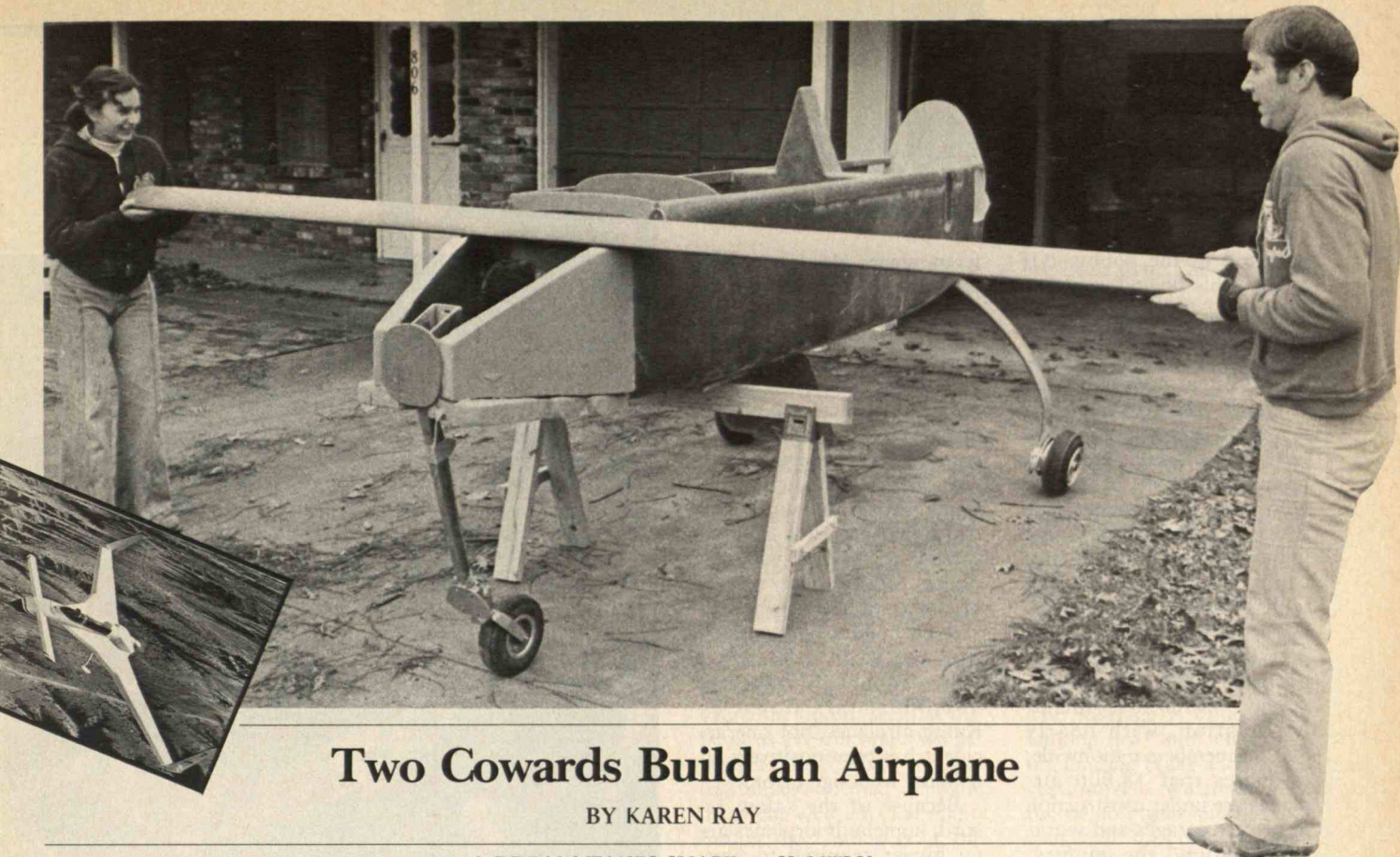
It is perhaps no coincidence that the next airborne challenge—a flight around the world without stopping or refueling, a distance of 22,858 miles—will be met by an airplane with its roots in the homebuilt movement. The challenge has already taken its toll. Tom Jewett of Quickie Aircraft was killed last summer when the Free Enterprise—a single-place, single-engine monoplane that was to circle the earth in 80 hours—dove into the ground in an emergency landing during a test flight.

Rutan, naturally, has designs on the world flight. His contender, dubbed World Voyager, has been described as a cross between the Defiant, a sailplane, and two fuel tanks. It will have two engines, with only one at a time to be used during most of the flight. In addition to 1,400 gallons of fuel, the plane will carry two people—Rutan’s brother Dick and Jeana Yeager.

Dick Rutan already holds several world records in his customized Long-EZ: longest distance in a straight line, 4,563.7 miles; longest distance in a closed circuit, 4,800 miles; and speed for 1,000 kilometers in a closed course, 207.99 miles per hour. Yeager holds her own record for speed in a 2,000 kilometer closed course—204.59 miles per hour—using the same plane.

The Rutans have a long history of success and there’s no reason to believe they won’t bring home the trophy. “I know of no one else,” says Dick, “who has a credible chance of making the flight.” And though the trophy will probably rest at the Rutan Aircraft Factory, there’s a whole nation of homebuilders who are going to think that the trophy belongs, just a little bit, to them.

ELAINE DE MAN, a free-lance writer in Alameda, Calif., has an M.S. in biology from San Francisco State University. JORDAN COONRAD is a photographer specializing in airplanes. They have a Thorp T-18 airplane in their garage that has been “one month away from completion for the last six years.”



Two Cowards Build an Airplane

BY KAREN RAY

A DREAM TAKES SHAPE. . . SLOWLY.

THIS LONG-EZ, ABOUT 40 PERCENT FINISHED, WILL SOMEDAY SPEED ITS BUILDERS THROUGH THE SKY.

EVEN with three engineering degrees my husband Jeffrey has never been a mechanic, so when he first mentioned building an airplane I ignored him. Jeff had not built anything of substance since constructing a boyhood kayak—for which credit properly belongs to his mother.

Jeff began flying at 15 in the Boy Scouts. He earned the money for lessons and took his hobby more seriously than teenage boys usually take anything. Later, he added a clutch of ratings and instructor certificates.

All serious pilots, and most nonserious ones, want their own airplanes. Thus, Jeff persisted. So we visited the Rutan Aircraft Factory in Mojave, Calif., to see the object of his desire—called a Long-EZ—and to talk with its designer, Burt Rutan.

The Long-EZ hardly looks like an airplane at all. Its wings begin toward the front

of the fuselage, sweep back and out, and end in four-and-a-half-foot vertical “winglets.” Sprouting from the vicinity of its nose is what looks like a second but smaller set of wings. This “canard” provides the same aerodynamic function as the horizontal stabilizer on the tail of a conventional airplane. With its engine in the rear, the Long-EZ is tailless. The function of the vertical stabilizer, again normally in the rear, is taken over by the winglets.

The techniques used to build the Long-EZ are as unusual as its appearance. The plane, including structural members, is constructed of foam cores covered with fiberglass held in place with epoxy. This composite “sandwich” is not susceptible to fatigue or corrosion and is far stronger for its weight than traditional materials. Its light weight also helps make the airplane efficient—weight

is a constant concern.

An important advantage of these innovations is efficiency. Using the same engine as a two-seat Cessna, the Long-EZ flies faster—approximately 193 miles per hour versus 120 miles per hour—while burning the same amount of fuel. And it can fly over 2,000 miles without refueling.

Interested but Not Ready

Building this airplane is a two-person project, and if I was skeptical of Jeff's ability I was extremely suspicious of my own. I was, and still am, a novice pilot, and had generally ignored developing manual skills. However, we watched instructional films and were assured that while the foam and fiberglass techniques require care and precision, they are not especially difficult. Our inexperience didn't matter—even veteran airplane builders must learn

this method from scratch.

Two months later we paid \$225 for plans and newsletter updates. With that we became builders of Long-EZ number 798.

But we were still cautious. Most builders buy the \$3,400 Long-EZ kit, although the word “kit” is misleading, since it implies something on the order of “insert wing A into slot B.” The kit also does not include engine, instruments, and a great deal of hardware. It does include bolts of fiberglass cloth, a small roomful of foam, and gallons of epoxy. However, we began with just \$150 in materials to minimize our investment and test our enjoyment. We've been buying more materials ever since—though we sometimes have second thoughts—and our airplane is slowly taking shape.

Home airplane builders are an unusual lot. They tend to be independent, scruffy, and

Right: The author uses a homemade balance to prepare epoxy, which is made in small batches and mixed in precise proportions.



Below: Karen and Jeff work on part of the "spar" that will support the main wings.

addicted to the hobby. (Of course, this doesn't apply to us.) Some more generalizations: Homebuilders have historically been tinkers, people often more interested in the process than the product. Many are not even pilots. However, lately there are more builders like us, people who want an airplane. The reason we build them is that without federal funding you can't buy a small airplane with Long-EZ performance. We estimate that, including everything, ours should cost about \$11,000.

The Experimental Aircraft Association, with nearly 80,000 members nationwide, estimates that 18,000 airplanes are under construction in private garages and workshops around the country, and that 10,000 homebuilt airplanes are flying in this country. Rutan estimates that half the people who buy his plans actually begin building, and 20 to 30 percent finish within three years.

Our Long-EZ and all other homebuilt planes are classed by the Federal Aviation Administration (FAA) as "Experimental—amateur built." To receive an airworthiness certificate in this category, 51 percent of the plane must be amateur constructed and it must be used for recreation, education, or instruction. Flying over congested areas is limited, pilots must tell air-traffic controllers they are in an experimental craft, the plane is confined to a test area for the first several dozen flight hours, and it is never allowed to make commercial passenger flights.

These restrictions are for safety—an issue on every homebuilder's mind, and certainly on this homebuilder's mind. An FAA examiner checks each airplane at dif-

ferent stages of construction, and the plans include numerous self-checks. Indeed, the safety record for homebuilts is very good, comparable to and sometimes even better than similar factory-built aircraft. Liability insurance costs about the same.

Safety is also on the designer's mind. On our factory trip Burt Rutan was asked if three-year-old epoxy is still usable. "It's probably okay," he answered. "But if I were you I'd build a boat with it. You can swim a lot better than you can fly." In over 100,000 hours flown by Rutan airplanes, not one accident has been positively attributed to design error.

Because of the safety record, homebuilt airplanes are no longer required to have their airworthiness certificates renewed each year. Builders can obtain a certificate permitting them to do their own maintenance and annual inspection. However, if the airplane is sold, the new owner must have annual inspections done by a licensed airplane mechanic. A homebuilder who sells a defective airplane is liable, as any other manufacturer would be.

On-the-Job Training

We began our adventure by cleaning and painting the garage. Then we made a table for building the airplane and a balance for measuring epoxy. Anyone who has ever used drugstore epoxy, mixing together the goo from two tubes, knows that epoxy is a bit of a bother, but the results are usually worth it. The "Safe-T-Poxy" system we use is the same only more so on both counts. Epoxy is used not only to hold the fiberglass in a strong, hard surface, but also to glue pieces of foam



together and even in making structural bonds. I've also found it useful in repairing shoes.

Every miracle product has its shortcomings. The hardener and resin must be mixed in proportions of 43 to 100 by weight—hence the balance. Too much hardener makes it heavy and less heat resistant; too little hardener and it will not cure properly. In batches larger than six ounces the chemical reaction can occur too quickly, making the epoxy very hot and unusable. One of our bigger batches melted through its plastic cup—paper cups are recommended. Mixed epoxy has a useful life of only 35 minutes. And while laboratory tests have shown Safe-T-Poxy to be free of serious health effects (it received an unusual "zero" rating in the standard skin test used by the plastics industry), a surprising number of builders have had severe allergic reactions

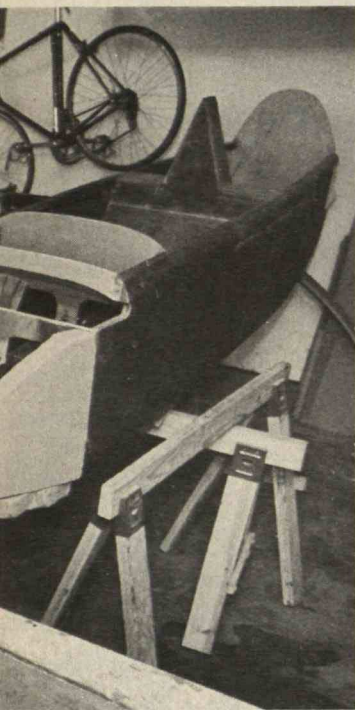
and have been forced to take extreme precautions or revert to older epoxy systems.

Early Discouragement

The first airplane parts we built were the seat backs. On one piece we didn't realize until the fiberglass cloth was wet with epoxy that it didn't quite cover the foam. We quickly learned that you don't reposition wet fiberglass cloth. Also, the cloth wasn't bonding to the foam. Discouraged, we thought our materials were defective. But after consulting with another builder, we realized that we needed to add miniature glass bubbles to the epoxy for a good bond.

After rebuilding the first pieces without incident, we made the instrument panel and other bulkheads that support the fuselage. The fuselage shell is built as two sides and a bottom. Three months after cleaning the

Right: After an early mistake in building the fuselage, they now read the plans independently and confirm each other's work.



garage we were ready to glass the inside of the left fuselage.

That "layup" went beautifully, with both of us stirring up epoxy, spreading it across the large surface, wetting cloth, squeegeeing off excess epoxy, moving quickly every minute. The job took us two and a half hours from first stir of epoxy to removing surgical gloves, plus another half-hour for preparing the epoxy. All that evening we were proud new parents popping into the garage to check on the baby. It slept well and so did we.

The next day we almost chucked the whole project.

We discovered, as Jeff describes it in our builder's log, a "fatal mistake." We had positioned three small wood supports one inch too far to the north. Jeff misread the measurement and on trial fitting we didn't see the one-inch gap as extraordinary. However, it meant that the wing support would not fit



Below: Working from underneath, Jeff adjusts the landing gear in the nose of the airplane.



through the fuselage. The piece was worthless.

Rarely have I wanted so badly and been so powerless to cheer someone up. "Maybe we're not cut out to be airplane builders," Jeff said. How could I disagree after my early skepticism? Were we setting ourselves up for more of the same, with the whole fuselage or a wing? Perhaps, but neither of us wanted to quit, so with additional checks—we would read the plans independently and confirm each other's work—we continued. In addition to the cost in disappointment and time, that was a \$150 mistake.

Although the consensus among homebuilders is that Rutan's plans are among the best in the business, they still cause much frustration. For example, they contain engineering drawings in only two perspectives, describe complicated tasks with little or no detail, and call for tools

we've never heard of and are not on the tool list.

I once checked with Rutan Aircraft to see what knowledge builders were assumed to have. "You don't have to know anything," was the answer. "Any idiot can build this airplane." I would amend that to: "Any conscientious idiot with lots of patience, a good tool collection, plenty of spare time, good coordination, and an enthusiastic and talented co-builder can build this airplane."

Over time the work blends together; challenges already overcome do not seem as difficult as present ones. We assembled the fuselage in a successful session that, as many do, went well into the night. Fitting the landing gear, the plans say, is a two-hour job. We worked on it for over three days. Shaping the fuselage outside, a "three-hour job," also took three days. Fiberglassing the outside of the fuselage must be done in one day, in two back-breaking, side-stretching sessions. When we finished that job, the accomplishment lit up the garage.

More Than an Airplane

Through this project we've learned a tremendous amount about patience, working together, and priorities, as well as a myriad of manual skills. Because our abilities are always improving, it is sometimes discouraging to look at pieces we made long ago and know we could do better now. But since we know everything is at least safe, it is, I think, better to be philosophical about such things than to worry about them.

Despite our care we have made more mistakes. Although the finished airplane has only one canard,

we built two. The first time we made several tiny errors that resulted in a canard that wasn't perfectly straight. Imagine aligning a suspended 12-foot piece of cooked spaghetti to microscopic straightness and you have an idea of the difficulty in aligning a canard. Other problems have been fixable, although sometimes requiring consultation with another builder or reassurance from Rutan Aircraft.

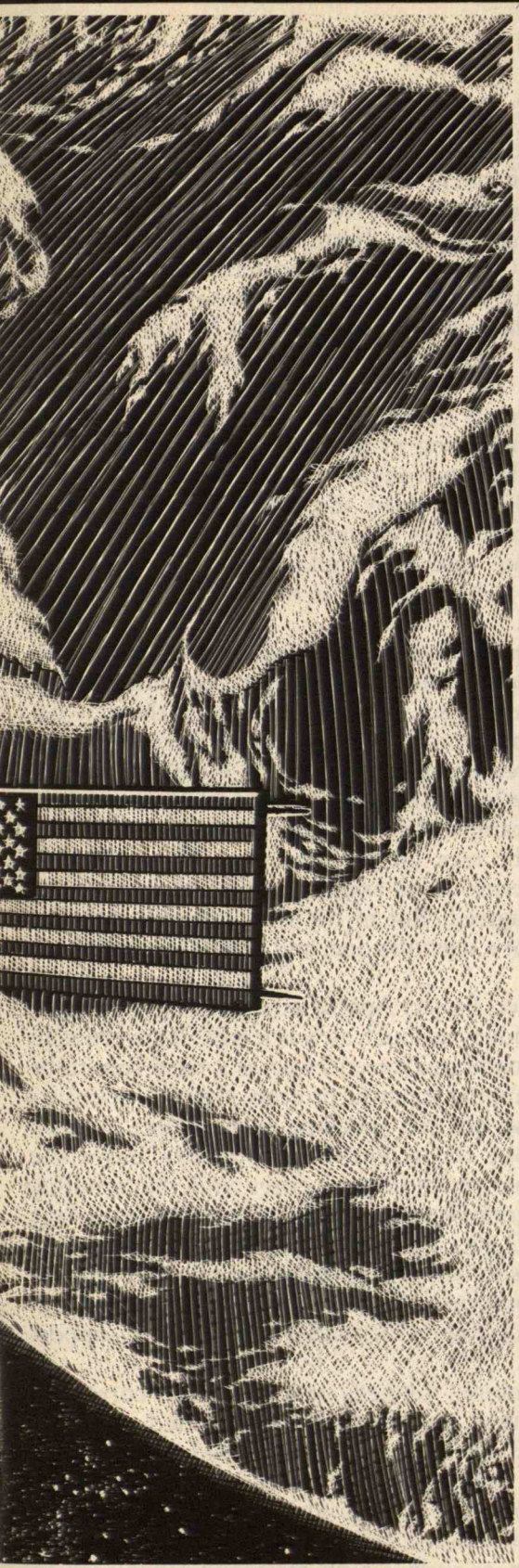
We are now nearly three-quarters of the way into our original two-year schedule. The fuselage is done, main landing gear and wheels are on, landing brake and canard are complete. We are at work on the nose gear and the spar that will support the main wings. That is about 40 percent of the airplane. The second Long-EZ, built by Mike and Sally Melville of Rutan Aircraft, took 1,200 hours to build. Rutan estimates most builders will need 1,000 to 2,500 hours. So far we have put in over 800 hours, not including discussions, worry, and trips to the hardware store.

The skills we have learned in those hours do not mean we are better people. Drilling a straight hole does not imply integrity, riveting does not impart generosity, and perfecting fiberglass technique is not the same as perfecting character. But a large project that is challenging, complicated, and elegant has its own rewards and teaches its own lessons.

It is almost a fringe benefit when the project will also fly. □

KAREN RAY, formerly a staff editor at *Technology Review*, lives in Arlington, Tex. Her second novel, *Family Portrait*, will be published in October.





After 25 years of research and development, space holds commercial promise. Will nations now compete or cooperate, or pursue a little of each, for their mutual benefit?

Managing the Enterprise in Space

THE exploration of space appealed to the human imagination long before it became possible. Jules Verne conceived of a voyage to the moon in 1865 and wrote about it with considerable technical realism. H. G. Wells also envisioned space travel in *War of the Worlds*. Indeed, nineteenth-century fiction was much more foresighted about space than about aviation.

Space, like atomic energy, was a technological endeavor initiated by the military. But the motivations of many of the space-science pioneers were nonmilitary: their visions were of people in space and human exploration of the solar system. If these goals had to be achieved under the guise of military necessity, scientists were prepared to suppress their real priorities to secure governmental support. Even Werner von Braun and his German team appear to have been mainly interested in exploring space, and saw the V-2 rocket program as the most feasible first step toward the realization of their dream.

BY HARVEY BROOKS

ILLUSTRATIONS: DOUG SMITH

Space technology soon reached a point at which priorities began to diverge: policymakers could begin to see political, as well as military, advantages to achievements in space. In the United States, a 1946 report by the Rand Corp. urged that the air force mount an effort to launch orbiting satellites. This would foreclose the possibility, the authors argued, of adverse political effects if a relatively backward power—for example, the Soviet Union—were to succeed in orbiting a satellite first.

But the political significance of spectacular high technology in its own terms was still not appreciated, and rocketry continued to be viewed in terms of near-term military applications. Similarly, Arthur Clarke's original proposal, in 1945, for launching a communications satellite in geostationary orbit was not taken seriously by engineers and politicians until more than 20 years later. Satellite development, though not dropped, was given low priority. Satellites were treated as scientific toys, intriguing to the imagination but not important enough to interfere with more urgent military developments.

When Science and Politics Mix

The Soviet launch of an orbiting satellite in 1957, using a military booster, amply confirmed the predictions of the Rand authors: it completely transformed political attitudes not only in the United States but around the world. Not since the explosion of an atomic bomb over Hiroshima had a technological event provoked such immediate and far-reaching political reactions. Sputnik was an extraordinary shock. But although its technological importance was enormously exaggerated—and by a good many who, with the wisdom of hindsight, should have known better—its political and psychological effects were not.

Sputnik, and other Soviet space achievements of the years immediately thereafter, created a crisis of confidence in American power and moral leadership. World leaders started believing that Americans had become complacent and had confused their priorities. The tail fins just appearing on American cars became the visible symbols of decadence and the misallocation of the country's engineering talents.

Such political setbacks would probably have become far more serious had the United States not risen so promptly and visibly to the Soviet challenge. Several responses were made in quick succession: the

National Defense Education Act, designed to identify and recruit talent for science and engineering, was passed; the curriculum-reform movement to improve science teaching was born; the President's Science Advisory Committee was transferred to the White House with a full-time science advisor reporting directly to the president; and funding for basic science, across the whole spectrum of disciplines, was sharply increased. The 1960 presidential campaign saw an unprecedented emergence of science and technology issues, culminating in the Kennedy commitment, in 1961, to land astronauts on the moon and return them safely to earth by the end of the decade. Congress approved this commitment with only one dissenting vote, and was applauded by the press, the American public, and most opinion leaders around the world.

The scientific community viewed all this with some ambivalence. It was nice to be loved and famous, but all but a few space scientists feared that the new national emphasis on technological spectacles would consume resources better spent on more valuable research. President Kennedy's science advisory committee, for example, felt that the investment in Project Apollo—the race for the moon—could not be justified in terms of its expected scientific results, and Kennedy agreed. But in his view it was a political project, not a scientific one, and that was justification enough.

Moreover, Project Apollo would not cut into other research money as much as was feared. If government R&D expenditures were viewed as a fixed sum to be allocated among scientific projects, then few scientists would have advised spending such a large part on Apollo. But the scientific community has since learned that technological crises and the resulting crash programs have served to increase the size of the total R&D pie, rather than to reallocate relatively fixed funds to new and undeserving priorities. Apollo did not compete with other federally supported science projects, but in fact pulled their levels of support up with it.

Furthermore, Kennedy was probably correct in thinking that circumstances demanded a highly visible and easily understandable demonstration of American technological prowess, not only to offset the psychological damage of Sputnik but the Bay of Pigs fiasco and the confrontation with the Soviets over Berlin as well. Apollo provided the means of such a demonstration without directly threatening

the Soviet Union or raising public fears of military confrontation. It was like "single-combat warfare": a challenge between the champions of two evenly matched medieval armies in place of a bloody standoff.

What is remarkable in the wake of later, more faltering federal commitments, such as "energy independence," the War on Poverty, and the cleanup of the environment, is the fact that Apollo was sustained with so little change during more than eight years of political turbulence. Apollo was in fact an easier goal to accomplish, but its success also derived from the skills of Jim Webb, the dynamic administrator appointed by Kennedy, who was able to insulate the technological integrity of the program from political sniping. Only in the defense field, which usually enjoys the advantage of security classification to screen it from too much public scrutiny, have any other American technological commitments been comparatively steadfast.

A Legacy to Management

The underlying principles of the American space program have remained surprisingly constant. They include the following features:

- The separation of military and civilian space activities to the greatest degree feasible.
- Considerable openness in the program, manifested by a strong emphasis on public information and a willingness to expose mistakes as well as successes.
- A strong international orientation. The Space Act declares that the United States is to exploit space for



There is
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well as R&D?

"peaceful purposes for the benefit of all mankind" and mandates "cooperation by the U.S. with other nations and groups of nations." However, this cooperation presumes "preservation of the role of the U.S. as a leader in aeronautical and space science and technology."

□ A government-directed program managed by civil-service laboratories, but with more than 80 percent of the activity delegated to a host of contractors and subcontractors. This follows the mandate of the act for "the most effective utilization of the scientific and engineering resources of the United States," and follows the pattern originally set by the Office of Scientific Research and Development during World War II and later copied in the legislation creating the Atomic

Energy Commission, the National Science Foundation, and the National Institutes of Health.

Such a pattern of "devolution" of management was particularly difficult in a program as intricate as Apollo. Hundreds of private organizations under contract had to be orchestrated, not only in connection with development, design, and construction but also, from Houston and Cape Canaveral, in the actual conduct of rocket flights. The resulting management structure was a unique blend of hierarchy and collegiality that has become the standard for other high-technology undertakings. In fact, the space program's greatest achievement may well be its contribution to the art of management.

But Apollo also contained a number of fundamental tensions and contradictions that have persisted. They were prominent in the national debate that led to the passing of the 1958 act and are still very much

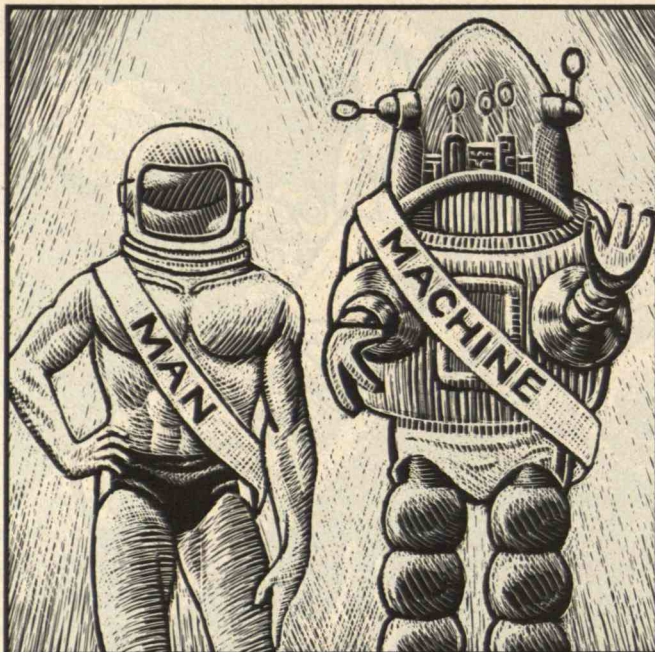
in the forefront of national discussion about the future of the space program.

Who Manages What and When?

There has always been a basic conflict over who should head the space program: should a single agency—the National Aeronautics and Space Administration (NASA)—be responsible not only for research and development but for routine operations as well? At first, this problem was latent. Few of the framers of the Space Act envisioned a day when space would become the site of routine operations, and almost no one anticipated how quickly this would happen. Therefore, the question of who should manage commercial space services seemed largely academic and received little attention early on.

The only NASA responsibility that could be described as routine involved launching and tracking, but these functions were viewed primarily as research-oriented. Even Apollo, though “operational” in a sense, was too experimental to present administrative conflicts: there were no “users” outside of NASA itself, and the hardware was largely handmade rather than mass-produced.

But responsibility for ongoing operations quickly became an issue as weather observation, then communications, and most recently, remote sensing and navigation from space platforms became possible. Each was an alternate means of providing a routine service already under the jurisdiction of other government or private agencies using more traditional technologies. Because its responsibility was only to generate technology, not apply it, NASA tended to



The practical function of people in space is questionable. Humans may have no incontestable advantages that cannot be overcome by ingenious design.

give rather low priority to the needs of potential users—it remained a “technology-push” rather than a “market-pull” organization. (Some critics described NASA’s function as generating “solutions looking for problems.”)

Of course, such a problem exists in any high-technology enterprise. The transition from development to commercial application is always difficult, partly because improvements in technology occur more rapidly than revenue from operations can recover the costs of development. In NASA’s case, this split has been exacerbated by the agency’s limited mandate and the budget structure of the federal government, which makes no distinction between straight expenditures and investments that produce revenue (or its equivalent) over time. Similar prob-

lems have plagued the government’s nuclear power program, particularly in providing uranium-enrichment services and managing radioactive wastes. Indeed, some of the problems facing the administrators of the space program are the product of their own successes.

Future directions are hard to foresee. Routine operations would appear to be amenable to a corporate form of organization, as in the case of the COMSAT Corp. Even for operations that require continuing subsidies, a public corporation analogous to the Tennessee Valley Authority would appear to offer greater flexibility than a federal agency. The problem of smoothing the transition from R&D to operations would remain, but competition for jurisdiction might be reduced, especially if the corporation were authorized to raise capital funds in the bond market

without competing for federal appropriations.

Whose Place in Space?

As early as 1961, many scientists believed that human presence in space was unnecessary. They felt that virtually all the scientific objectives of the program could be attained at much lower cost, and with substantially less political risk, by using remote-controlled unmanned vehicles. But they conceded that this might require a considerably longer-term program. Others argued that the advantage of having on-the-spot human judgment outweighed the risks of losing lives during a mission. In the end, manned space projects won out. The political imperatives of beating the Russians, the time pressures, and undoubtedly the romantic dreams of science-fiction writers all influenced this choice. But the persistent fear of the scientific community throughout the debate—that the inevitable budgetary overruns in such a large program, with so many technical risks and uncertainties, would ultimately crowd out more scientifically rewarding unmanned space experiments—was partially realized.

The idea of sending people into space continues to have great popular appeal, as seen in the revival of public enthusiasm for the first flights of the shuttle. And manned exploration of the near planets remains a glamorous and appealing goal, while even serious scientists continue to talk of space colonies and factories on the moon.

People do have one incontestable advantage when on-location in space: they are part of a feedback loop with a much shorter time delay than when they are located on earth. This communications delay is immutably set by the velocity of light and cannot be fully compensated by even the most elaborate signal processing. Thus, the need for a quick on-site decision may not be adequately fulfilled by an earth-bound operator—the response may come too late. But are such events frequent or important enough to significantly hamper unmanned explorations?

In the 20 years since the first U.S. commitment to Apollo, tremendous progress in sensors, automation, and communications technology has transformed the comparative advantages between humans and machines. Many more observers now question whether there is any practical function for people in space—apart from the ever-present elements of popular appeal and political posturing. Humans may have

no incontestable advantages in space that cannot be overcome by ingenious design.

Another important argument favoring the unmanned approach is that the technology is more likely to be adaptable to other uses. Robots used in space, for example, can be directly applied to factories and mines on earth. And space projects such as automatic manufacturing systems, which would replicate themselves in new locations, might also be used to build remote-controlled industrial operations in deep oceans, at great depths in the earth, or in many other situations inhospitable to humans (such as fires or high-radiation environments). By contrast, the technology necessary to support people in the hostile environment of space is much more specialized and less easily applied to other areas. Of course, scientists can acquire incidental knowledge from observing human responses in space—under conditions of weightlessness, say—but the benefits are small relative to the costs of developing and implementing the technology.

The problem that surfaced during Apollo—of budgetary overruns in costly manned programs that disrupted unmanned science and applications programs—has become even more acute with the shuttle. And budgetary restrictions are much more severe now than in the 1960s. Moreover, both Europe and Japan are developing impressive unmanned space capabilities with total budgets less than one-fifth that of the United States.

For example, the French and Japanese are now competing with the United States in developing expendable boosters, communications, and remote sensing satellites—partly a result of NASA's resources being largely consumed by the shuttle. Thus, the United States may be undermining its own long-range competitiveness in space-based commercial services with the inflexibility of its manned programs. The problem is not just the size of these programs, or the tendency to underestimate their cost, but their "lumpiness": they form a single integrated package whose elements cannot be constrained without serious risk to the whole program.

Would manned space efforts continue to enjoy such high priority in the United States in the absence of political competition with the Soviet Union? After all, if the United States were to devote the same effort to applications and sciences, as well as basic aeronautical technology (also a NASA responsibility), the long-term benefits to U.S. competitiveness in high

technology would be greatly enhanced.

But in the long run, the answer to this question is not so simple. Although budgetary competition within NASA is not a law of nature—there is no inherent reason why shuttle overruns should compete with other NASA programs rather than with other government programs of lower priority—the manned-versus-unmanned debate is likely to continue, especially as the space budget becomes increasingly constrained. Politicians are likely to take the side of the manned space activities, as they did in 1961, while most, though by no means all, of the scientific community is likely to be on the side of the machines.

The issue for the future is not so much whether to use the shuttle technology to enable human workers to service, repair, or replace equipment in earth orbit. The technology to do that is here and will undoubtedly become more reliable and cost-effective. The question is: Should there be any *further* development of manned capabilities, say, for platforms in earth orbit, planetary exploration, or permanent space stations? These developments would eclipse automated alternatives.

One possible compromise would be to consider developing manned capabilities only after automated means appeared to be reaching a point of diminishing returns that could be revitalized by the introduction of humans. The benefits of manned activities would be deemed insufficient to warrant investment unless the results of unmanned missions strongly justified them. In other words, manned space activities might in the future be driven more by the market pull of unmanned activities than by the technology push of what is already possible—and politically expedient.

Piggybacking in Space

From the beginning of the space program, there has been a debate over civilian versus military functions: Was it realistic to try to separate them when they had so many technologies in common? Would a civilian space agency such as NASA draw critical resources and talent away from what many saw as a more urgent military space effort? And given the overlap of technologies, would much of the civilian agency's data have to be classified?

The latter issue arose in the debate between proponents of earth orbiter and lunar orbiter approaches to the moon landing. A strong argument for the former

was that the technology could be more readily adapted to military uses. But although the joint-use debate receded when the lunar orbiter was chosen, it has once again surfaced with the advent of the shuttle, which is capable of carrying both military and civilian payloads on the same mission.

I believe the separation of civilian and military space activities has served the country well and should be maintained. But it will become increasingly difficult to do so as budgetary pressures and economies of scale combine to favor using a single space platform or vehicle for a variety of missions. The issue, in fact, is not only one of civilian versus military missions but of multipurpose versus single-purpose projects in general. But will combining missions really save money? When the technical and managerial complexity of multipurpose missions is fully considered, separate missions may be far more appealing. Moreover, the multimission approach may compromise individual programs.

The marriage of military and civilian missions in the same platform or vehicle introduces further complications. There are likely to be continual controversies over classified information, as managers of civilian payloads may be denied access to information necessary for fulfilling their duties. Secrecy will cause particular friction when foreign payloads are involved. Military programs will be seen as limiting civilian flight opportunities, and nations unsympathetic to U.S. security objectives or foreign policy might be reluctant to participate in a partially military mission. Ironically, American efforts to combine military and civilian payloads are likely to stimulate other countries to develop their own space services.

However, such competition has both benefits and costs. Breaking the U.S. monopoly in space will stimulate greater innovation on the part of American space-vehicle managers. Consumers of space services, both U.S. and foreign, would thus likely profit. On the other hand, would the benefits of competition offset the costs of unnecessary duplication?

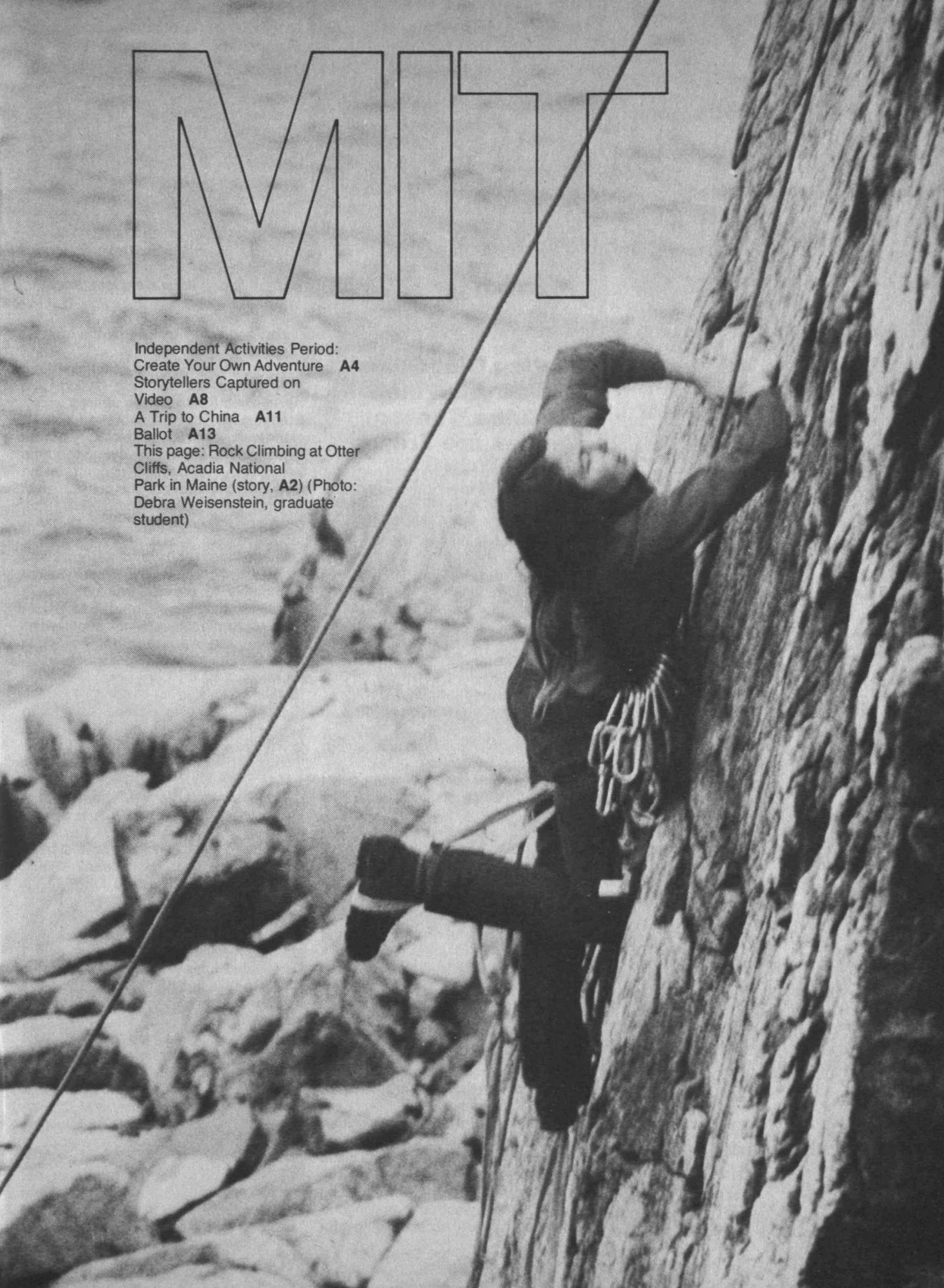
It is not clear which types of space services are best treated as "natural monopolies," and thus provided cooperatively, and which are more naturally competitive. But American efforts to save money by combining military and civilian space activities could stimulate foreign competition whether appropriate or not. And even if a more competitive environment in space were desirable, militarizing the U.S. space program would be an awkward way to bring it about.

MIT

Independent Activities Period:
Create Your Own Adventure **A4**
Storytellers Captured on
Video **A8**

A Trip to China **A11**
Ballot **A13**

This page: Rock Climbing at Otter
Cliffs, Acadia National
Park in Maine (story, **A2**) (Photo:
Debra Weisenstein, graduate
student)





Outing Club: Your Water is Fine, But the Contact Lenses are Frozen

"Can you imagine cooking dinner for four on a one-burner stove balanced on your snow shoes so it won't melt into the snow? Going to sleep with your water bottle in your sleeping bag to keep it from freezing . . . Waking up in the morning to find your water is fine, but your contact lenses are frozen in their cleaning solution?"

"The M.I.T. Outing Club affords an opportunity to have these experiences—and to meet people in an entirely different way than going to see a movie—you canoe, cook dinner, build an igloo (only to have it cave in when you put the next-to-last blocks on the roof)," says Laura Moser, an active participant and sophomore at Wellesley. "It's a very different situation from doing problem sets—different qualities come out. Situations range from a hike that resembles a family outing to a possible emergency rescue situation."

The groups are usually split about 50-50—the regular participants who know each other and new people who don't know anyone. For some it's a first-time-ever in the mountains, or on white water in a canoe; and for many of these it sticks, opening new ways to escape from the routine of M.I.T.—and of life thereafter. "We love to see new faces," adds Ms. Moser, who edits *GNARMPFSK*, the outing club newsletter. The title? No one knows what it means, but perhaps some alumni readers can explain what happened in the early sixties to give *GNARMPFSK* its name.

The Outing Club dates back much further than that—in fact, it is one of the oldest college outdoor clubs in the United States. Details before 1948 are not well known, but since then the M.I.T. Outing Club has been very active, in making the outdoors both more accessible to stu-

This page, left: Rob Heineman, '84, "aid climbing" (hanging on chocks and pitons hammered into the rocks) about 80 feet above the ground at "Kansas City" in Shawangunks, N.Y. Bottom: Cohasset, Mass., whitewater canoeing.

Opposite page, clockwise from top left: Intervale, N.H., cabin under construction; Rob Heineman, '84, in Shawangunks, N.Y.; Steven Niessner, '82, knee-deep in heavy snow at Freemont Peak (13,745 feet) in Wind River Range, Wyoming; Steven Pollock, '82, at Seneco, W. Va. "Triple S" climb. (Photos: Rob Heineman, Debra Weisenstein, graduate student, and Steven Niessner)

dents, and safely utilized by them, at all times of the year.

In the early 1950s, the club helped put together the Intercollegiate Outing Club Association (IOCA) which shared expertise from the more established college clubs with new clubs. Exploratory efforts in technical rock climbing during this time led to a number of first ascents in the New England area and the publication of *Fundamentals of Rock Climbing* in 1956, an introductory text on rock climbing technique.

In the late 1950s and early 1960s, other activities grew: the Winter Safety Committee to provide training in safe winter climbing; an Adirondak Mountain Club winter mountaineering school which became the Appalachian Mountain Club's Winter Mountaineering School offered each year in the week following Christmas.

The M.I.T. Outing Club now owns two cabins that form a base for activities in the White Mountains of New Hampshire. One began with a donation of \$500 by an MITOC alumnus in 1948, used to purchase land at Intervale, N.H., near Mount Washington. Then two units from the first married student housing on the West Campus, where Westgate now stands, were moved there in the early 1950s. They frequently hosted 40 to 60 M.I.T. people in the course of a weekend.

The opening of Route 93 made the western side of the White Mountains more accessible, and plans were begun for a cabin there. Land near Plymouth, N.H., was leased in 1971 from Rockwell International for \$1 a year. The stage was set for the building of a second cabin, known as Camelot, which now provides a White Mountain western anchor for M.I.T. activities.

In March 1979, the Intervale cabin burned to ground. But intrepid M.I.T. students spent the summer of 1980 building a new Intervale cabin and it was completed by that fall.

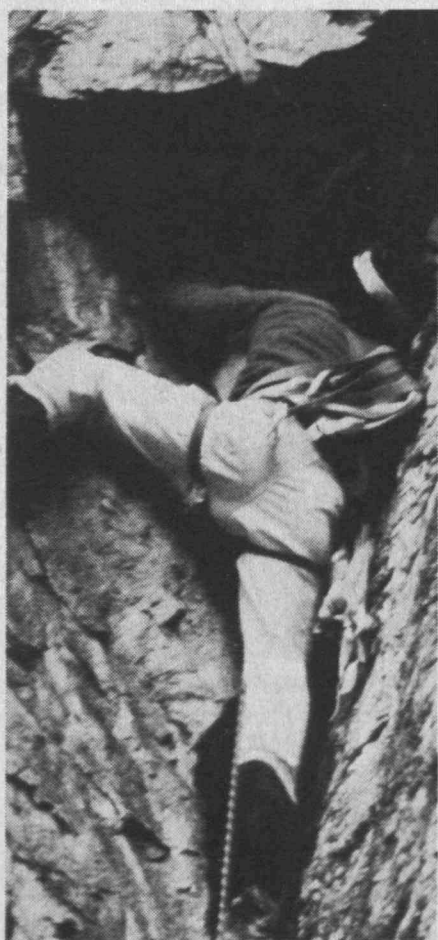
Currently both Intervale and Camelot cabins are used with enthusiasm. From the newsletter written by Laura Moser: "Visitors to Camelot will already find





green wood seasoning for the winter of '84 in the newly constructed woodshed behind the cabin, and beyond that is a freshly laid out ski trail . . . Many things are new at Intervale, including a basement door and window . . .

"It's impossible to spend three weekends in the winter mountains without becoming more knowledgeable and skillful in the out-of-doors. There's a good chance you'll learn more about yourself, too, as you learn to kick steps with your snowshoes, ski through silent evergreen forests and over frozen ponds, witness what the Milky Way is really supposed to look like, and discover the true meaning of warmth. . ."—M.L.



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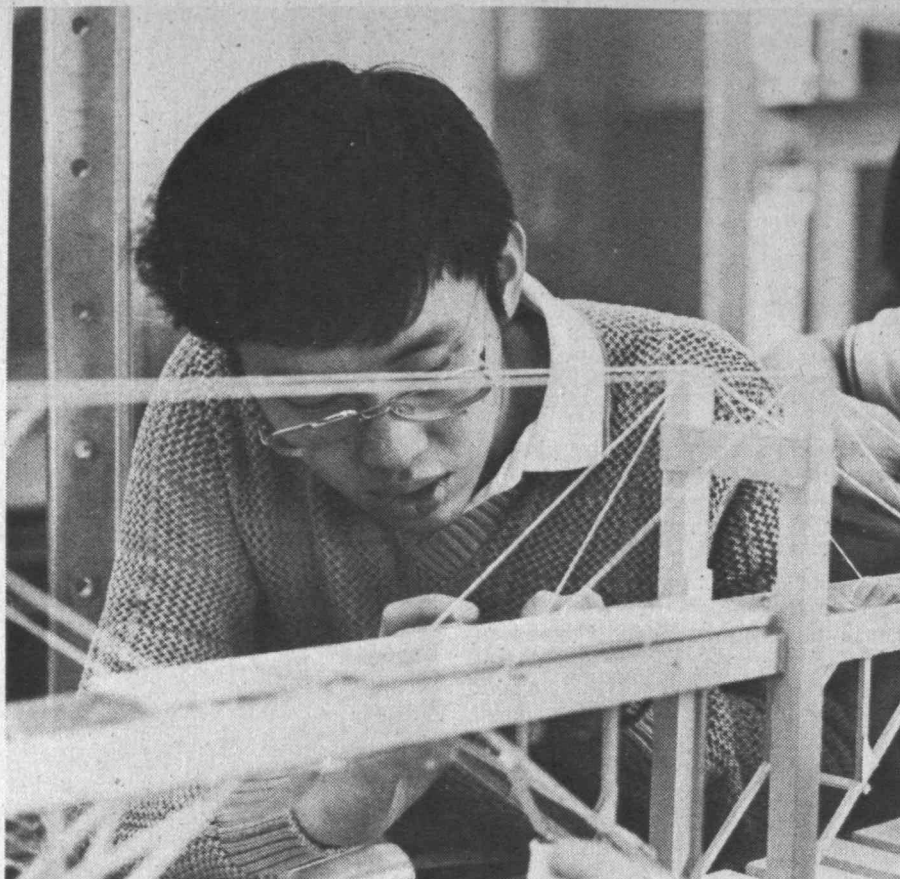
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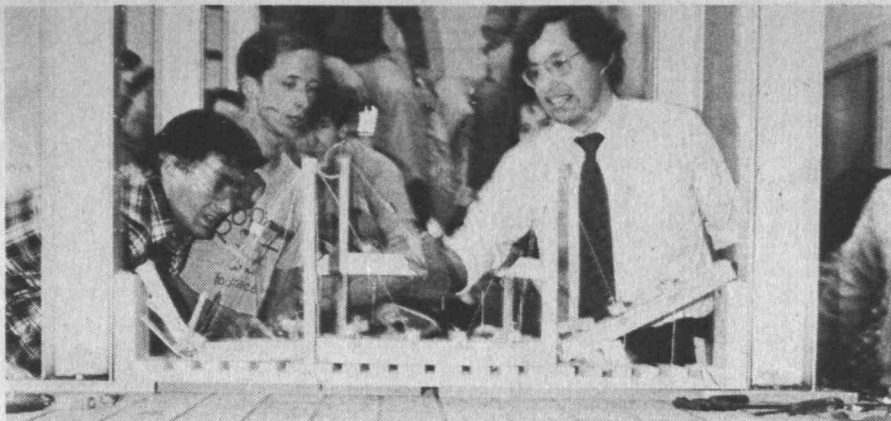
B. David Halpern, '43

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"Das Bridge: design contest. In honor of the centennial year for the Brooklyn Bridge, groups of three contestants were asked to build (with a standard kit of parts) a model suspension or cable-stayed bridge to carry a loaded cart

across the "river". Cash prizes were awarded to the top three entries with the highest combined scores in these areas: strength, deflection, weight, innovation, and aesthetic appeal. (Photos: James J. Snyder)



Independent Activities Period: Create Your Own Adventure

Ah to be invisible, sprout wings, and fly instantly to 20 places at once during I.A.P.! Peruse the guide from aeronautics and astronautics to Whitaker College; taste the offerings in linguistics, mathematics, music; or philosophy, physics, writing; or history, economics, psychology. Try your hand at drawing and your feet at square dancing; bend your limbs in Aikido and strengthen them with skiing; make paper airplanes or puppets; visit Russia. Test your mental agility, ponder religion, probe the far reaches of your imagination. Or how about, taste jelly beans . . .

They sit, beguiling, on the table, a fantastic array of oval colors, the sun making them shine through their neat little plastic bags, pulled askew by hands reaching in to lift their silken small shapes to eager mouths . . . jelly beans! Orange, yellow, white, red, light brown, dark brown, green. Faces mesmerized by the wonder of taste, scrutiny and concentration focused on indentifying correctly the flavor *just* by taste, eyes closed, not knowing the color or from which bag they came.

Quiet conversation punctuates the jelly bean tasting contest (the winner to guess the most flavors correctly): "This is a very vulnerable position, eyes closed, mouth open . . ." "Spearmint. It's like getting lost in a Dentyne factory . . ." "Chocolate?" "Yes." . . . "I don't know." (She looks down, shaking her head in anguish.) "Some kind of fruit." (Laughter). "It's peanut butter . . ." "I'm Paul and my brother and I went through three pounds of these over spring vacation." "You've been practicing. . ." "Are there any butterscotch?" "No, but the peanut butter will pass for anything . . ."

All over the Institute such scenes—many much more serious, many more physically or mentally demanding, some as light, characterize this month-long intersession devoted mostly to informal learning and teaching. Perhaps the best way to understand is that chosen by photographer James J. Snyder, '80, whose pictures are here.—M.L.

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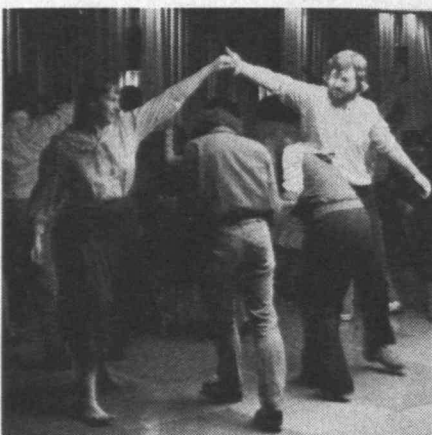
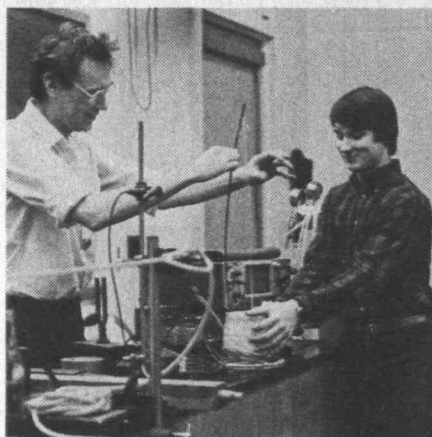
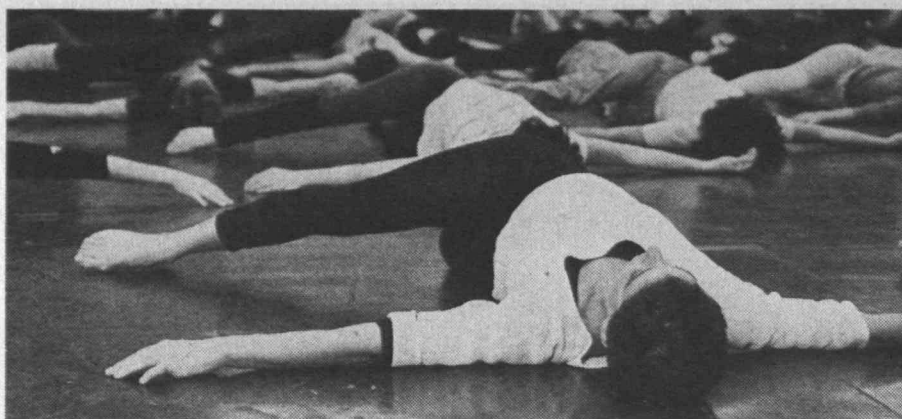
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*Clockwise from top: dance class;
"Seafood Fest", arranged by the Sea
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a wide assortment of the sea's
underutilized species" and learn their
history and nutritional value; a "music in
physics" lecture and demonstration by
Professor Walter H. G. Lewin; square
dancing; more "music in physics."
(Photos: James J. Snyder)*



Top: plant clinic: Professor Gordon DeWolfe, director of the Horticulture Department, Massachusetts Bay Community College, lectures. Participants brought healthy or sick

plants for advice on soil, bugs, light. Bottom: the fine art of jelly bean tasting—from pina coloda to chocolate. (Photos: James J. Snyder)

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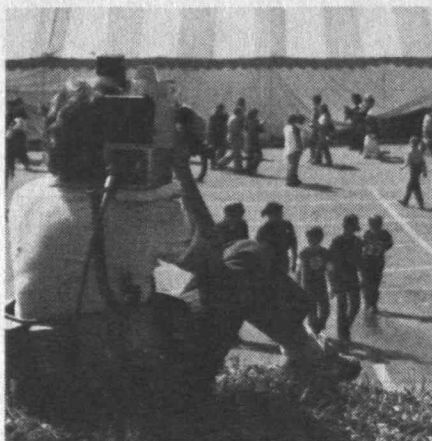
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Students Create a Video of Storytellers: "Observe, Participate, Wait . . ."



A video crew studying visual design in the department of architecture captures storytellers mesmerizing audiences in Jonesboro, Tenn. Students and staff are pictured in column three, this page. (Photos: Stephen Murphy, graduate student)

They mesmerize an audience. Styles vary: some have the preacher's pacing, gesticulating intensity; others are soft spoken, projecting a quiet magnetism, guaranteed to glue an audience to their every word.

These are storytellers—and they gather in the little town of Jonesboro, Tenn., each fall to spin their tales. The festival has been organized by the National Association for the Preservation and Perpetuation of Storytelling.

This year was a tenth anniversary—and instead of the usual ten or 12, 50 storytellers descended, bringing magic.

To preserve that magic, a group of staff members and students studying visual design in the department of architecture were on hand to film a documentary. "We as filmmakers are storytellers ourselves," explains Steven Kostant, graduate student and organizer of the expedition.

Three staff members (Glorianna Davenport, Benjamin Bergery, '79, and Mark Abbate, '77) and five graduate students (Stephen Murphy, Sara Griffith, Kate Purdie, Jim Campbell, and Steven Kostant) squeezed into two cars with all their equipment and drove to Tennessee in 17 hours. Then for five days they were intimately involved in the storyteller's world. They want to answer for everyone: Who are storytellers? What is a story? Why the need for a story? How do they swap stories? Where do they learn



them? How does storytelling fit with today's media and environment?

"We think of it as folklore, but it's truly a valid, viable art form," explains Mr. Kostant. "Video is particularly suited to storytellers, because they all try to capture a visual image—and they choreograph their stories, using elaborate gestures," says Mr. Kostant.

The students and faculty from M.I.T. watched performances, interviewed storytellers, talked to them for hours, listened.

And what a magical time it was. The stories deal with issues of life, death, pain, sadness, humor, charm.

"We did not want to exploit them—we became friends," says Mr. Kostant. He feels the storytellers felt an initial sense of reservations about the media, but then accepted the M.I.T. group into their community.

Students and faculty came back with a total of 16 hours of footage to be edited down to one or possibly two hours, and Mr. Kostant says the group will then have "the best and most significant documentary to date on storytelling"—and done on a shoe-string budget. The budget for a one-hour documentary for television ranges from \$100,000 to \$250,000; we spent \$2,500," he says (\$1,500 for film, \$500 for expenses, \$500 for transportation.)

The documentary is to be from an informative and lyrical perspective—so the

viewers leave elated, "as if they were listening to their grandmother sitting on the porch telling a story. Stories are a form of communication," explains Mr. Kostant, "but they are spiritually transcendent—close to religion, even a form of personal healing."

There is much to learn on such an expedition. A documentary film is a happening—there is no script. And there are multiple events simultaneously to cover. "How to establish a relationship with the subject" is of primary concern, explains Mr. Kostant. "One must observe, participate, wait." Their footage is a tribute to the M.I.T. film department's emphasis on the art of the documentary.—M.L.



Top: crowds were colorful; above: a group of storytellers.

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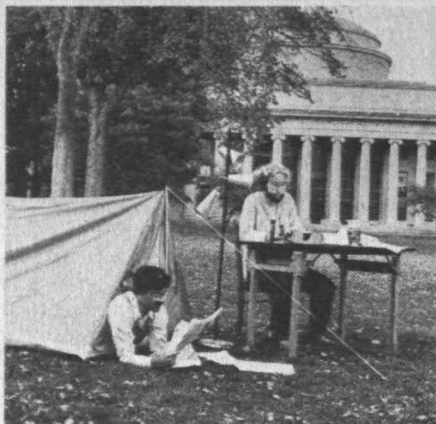
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Graduate Housing: Rents Up, New Space Coming

When conversion of the former Infirmary (once Sancta Maria Hospital) at 350 Memorial Drive into a graduate women's residence was completed ahead of schedule in January, a line formed quickly for the 39 rooms (31 singles, 8 doubles), and soon there was a waiting list.

No surprise, for as Ken Jacobs, chairman of *The Graduate*, wrote last winter,

"Dramatizing the housing problem. Pitching a tent in Killian Court is not really a solution, but Ken Jacobs, chairman of The Graduate, made the photograph his lead for the claim that 'the housing situation for M.I.T. graduate students could stand a fair amount of improvement.' Changes are coming. Rents in on-campus graduate housing will be raised, with the increased income supporting a reserve fund from which is to come additional housing—enough so that half of all graduate students will live on the campus by the mid-1990s."

"the housing situation for M.I.T. graduate students could stand a fair amount of improvement."

There's a perennial shortage of on-campus housing, despite construction in the 1960s and 1970s of over 600 apartments for graduate student families in Eastgate and Westgate and rooms for nearly 800 single graduate students (men and women) in Ashdown House and Tang Hall.

But as those numbers make clear, more than half of M.I.T.'s 4,500 graduate students must live off the campus, and therein lies the rub—"intolerable roommates, high rents, unsafe neighbor-

hoods, rooms so small the cockroaches feel crowded . . . obnoxious neighbors, crooked landlords," writes Mr. Jacobs.

The solution is simple—but out of reach: build more on-campus graduate student housing. To bring that goal nearer, M.I.T. is now establishing a Graduate Housing Reserve Fund. Rents in graduate student housing will be gradually moved upward toward "fair market value," and the excess of rental income over operating expenses will go to the reserve fund, eventually to be used for more housing. (Already the fund has been tapped for the money to refurbish the former Infirmary.) The goal is to provide housing for half of all graduate students by the mid-1990s; to meet it, says Mr. Jacobs, would require 300 more apartments for married students and 400 more single rooms.

The definition of "fair market value" is controversial, students in on-campus housing proclaiming that they already pay it, off-campus residents reveling in the prospect of "reduced inequity." Then people start talking about alternatives—money from alumni, money from the Institute, a tax on off-campus housing payments. But that debate, says Mr. Jacobs, is best left to the "rhetoricians."

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In China, Passengers Are Labeled; Hard Class Calls for Force

Helen Kauder, '83, is an economics major who spent last year studying in Taiwan. She travelled in China for some of that time (she speaks Chinese fluently). The following is excerpted from a report she wrote for the Boston Globe focussing on her experiences on trains in mainland China:

From the moment he tries to buy a ticket, the train traveler in China must contend with a system that seeks to keep him firmly in his place. Nowhere do Chinese and foreigner alike feel more labeled, categorized, and classified than on railway trains.

In what purports to be a classless society, there are no fewer than five classes of train travel to choose from. The variety is deceptive, however, as the foreigner is rarely given a choice, and the country peasant or university student generally can't afford anything but the least expensive option. As a foreigner and a student, and one who spoke the language as well, I was able to take advantage of the full range of options offered and became skilled in the art of Chinese rail-roading.

A train in China is a string of long, crowded and smoke-filled corridors, rows upon rows of bunk beds and, now and then, a few selected sleeping compartments. A "soft berth" ticket puts you in a sleeper with downy white sheets that is opulent by Chinese standards. Each little room is decorated with lace and heated in winter. One notch down, and in another car, is the "soft seat" class. A soft seat is similar to an Amtrak seat, but with the leg and reclining room of a dentist's chair. One is less pampered than in soft sleeper, but still supplied with tea, teacup, and hot water. Either soft class ticket buys very little contact with the masses.

Most cars of the train are "hard class," some being "hard berth" and the rest, the "hard seat" class. In berth there is a partition between every two sets of three-tiered bunk beds, a spartan arrangement that leaves little privacy but is wonderful for socializing. Each slightly padded vinyl bench is covered with a thin cotton mattress like a Japanese futon, and a pillow, blanket and towel are provided as well. A hard seat is unpleasant only for long rides or if the train is crowded, as breathing space is limited by the holders of the still cheaper ticket, the standby option, which permits you to sit only if a space is available. During peak seasons such as



Chinese New Year, it is not unusual to stand for the 36-hour journey from Canton to Peking. . . .

Sufficiently High Status

Since computers are not yet used to coordinate bookings, there is no way for a train official working in Xian, for example, to know which seats on the train coming from Peking, if any, are still available. The officials maintain that all seats are sold out and then have travelers buy a standby ticket for an unreserved seat. Shrewd Chinese don't bother, therefore, to wait in ticket lines in way stations. Instead, they spend a few pennies and buy a platform ticket, sold from a booth outside the station. It is not a real ticket: It permits you to board, but not to ride the train, and is in theory only bought by those wanting to see off family and friends. Once inside the train, people head for the center car where there is a service counter that changes and extends tickets based on the availability of space. The attendant behind this counter is powerful, as he determines who will be given any remaining beds or seats. Not surprisingly, passengers try very hard to be friendly to him.

I followed the platform ticket procedure in Suzhou, Xian, and once in Peking when, because it was dinner time, the station officials refused to open their

ticket windows. As long as there was one seat left on the train, I didn't have to worry. The attendant behind the service counter, feeling that my status was sufficiently high to merit special attention, insisted on taking care of me before he assigned seats to the Chinese passengers. My problem, however, was that when paying for the ticket, I was not sure whether the prices quoted to me were meant for the Chinese or were the foreign tourist prices of 75 to 100 percent more. My technique was to say that I was a *liu xuesheng*—a foreign student studying in China—and therefore expected to pay only the *liu xuesheng* price, roughly comparable to the Chinese price. The train officials would then invariably ask to see my student ID, which was unlike anything they had seen before. It was blue, whereas foreign students at Peking University had bright red IDs. Mine had the old-style Chinese characters, but only simplified characters were used on the red cards.

Mine was a student card from Taiwan.

"This is not an ID from China!" was the first reaction. On closer scrutiny, the officials would notice that it was dated "70-71" and hand it back to me saying it was too old. (The Republic of China considers itself in its 71st year, having been established in 1911, with the fall of the Manchu dynasty.) I would hesitate, and then explain that I was a student in Taiwan. "And

五环
租冲



is not Taiwan part of China?" I asked. Without further ado, I was quoted the *liu xuesheng* price.

Some Had Never Seen a Foreigner

Families with many children, young soldiers and the country peasants choose the hard seat option since it is about half the price of the sleeper. Some of them had never seen a foreigner at such close range and so didn't dare approach me. Others spoke timidly: how was it that I spoke Chinese—was I Taiwanese?—and was my hair naturally curly? Our conversations, although mundane, were warm and sincere.

The cadres and party officials with whom I waited in the soft class waiting room did not speak to me. Perhaps I was not enough of a novelty for them to bother. More likely, their silence indicated that, as party members subject to government scrutiny, they did not want to exhibit an interest in having relations with foreigners.

They had good reason to be careful. All Chinese are aware that unusually close contact with foreigners could arouse the suspicions of neighbors and co-workers. It is illegal for ordinary Chinese to accept gifts from foreigners—or to enter foreigners' hotels without a special permit.

My one unpleasant experience on the railroad came about because I, in the eyes of some train official, became too involved in the affairs of a Chinese passenger. On the train from Xian to Canton, comrade Li, a man in his mid-thirties, approached me to ask if he could practice his English with me. He only knew a few words, so the conversation quickly reverted into Chinese. He had entered university in 1965 but had stopped in 1968 to participate in the activities of the Cultural Revolution, and did not graduate until 1979. When I asked him what the activities had been he confessed that they had consisted almost entirely of putting up big posters, meant to spread revolutionary morale and propaganda. More often than not there was simply nothing to do.

Now he worked in a travel agency which organized tours for vacationing Chinese. It was a newly created post in a new agency which was in the process of designing agency stationary. He wondered if I could provide an English subtitle to accompany the Chinese logo.

When he learned that I was going to Canton, he suggested I visit his wife who worked in the provincial museum there. I nodded politely but pointed out that I would only be in Canton for a few hours. We did not discuss it further. He eventually went back to his seat, a hard berth like mine, but a few cars away, and I forgot him, but only temporarily.

I had to change trains in Wuhan, but my connection was not due in for half an hour. When I returned to the train station after a short walk to town, I was stopped by four or five train officials who would not let me onto the platform. Why, they wanted to know, was I travelling alone? Why was I going to Canton? They examined by travel permit and passport while I tried to figure out what was going on. The interrogation continued. Who was the person with whom I had gotten off the train? I myself did not know.

Then they reminded me of Comrade Li, who apparently had left a letter for me at the Wuhan train station to deliver to his wife in Canton. I vehemently denied that I had anything to do with Li and his wife. I was simply on my way out of the country. The curious bystanders in the station who had crowded around us now jumped in on my behalf to say I was just a foreigner and should therefore be left alone. The train authorities seemed satisfied and decided to let me board. I, however, was thoroughly shaken.

By the time I crossed the Canton-Hong Kong border, after two weeks and over 100 hours of rail adventures, I was so exhausted that I decided to buy a first-class ticket for the last stretch of the ride to Kowloon. But in the Hong Kong station, just a few feet from the gate to China, the first-class ticket booth had been boarded up and only ordinary tickets were being sold. Here at last was a classless train.



Previous page: In Shanghai, a man walking his bird. "Bird rearing is a hobby in China—they swing the bird as they walk and take great pleasure in listening to it sing," explains Helen Kauder, '83.

This page, top, left to right: In Suzhou, a man on the street with a wok; Barry Nalebuff, '80, friend, and Ms. Kauder; in Guangzhou, painting strips of red paper to be used on the door to houses to welcome the new year. Bottom: Suzhou garden. (Photos: Helen Kauder, Barry Nalebuff)

Alumni Election for the National Selection Committee

Ballots are due by May 14 in the 1983 Alumni Association national election. At stake are three seats (three-year terms) on the National Selection Committee, whose duties are to choose national officers of the Alumni Association and to nominate alumni members (five-year terms) of the MIT Corporation. The ballot is inserted to the left, and the nominees—one from each of the three districts is to be elected—are listed below.

District 3



Philip H. Dreissigacker
S.B. 1937, Mechanical Engineering
Vice President, Technology (Retired)
Farrel Machinery Div., Emhart Corp., Orange, CT

Alumni Association Morgan Award, 1980; Alumni Fund: Personal Solicitation 1980–81, Leadership Campaign, 1979–80; Reunion Gift Committee 1976–77, Special Gifts Chairman 1974–78; Alumni Council Term Member 1980; Educational Council: New Haven Area Chairman, 1974–present, Member 1971–present; MIT Club of New Haven: Director 1978–present, President 1980–82; Class of 1937 45th Reunion Committee Member 1982; MIT Sustaining Fellow: Annual Member 1980–present; Member: American Arbitration Association 1980–present; ASME 1940–present; ATO Fraternity; Registered Professional Engineer: Connecticut and Pennsylvania; Naugatuck Valley United Way: Board of Directors 1970–present; General Chairman 1979; Town of Orange Connecticut: Energy Conservation Commission 1981–82; Chairman, Town Bond Projects Building Committee 1982



Brian W. Moore
S.B. 1973, Mechanical Engineering
Senior Licensee Sponsor-Latin America International Division
C-E Power Systems, Windsor, CT

Alumni Fund: Personal Solicitation Solicitor 1978–83, Hartford Geo Telethon Solicitor 1980–81; Alumni Council: Member 1978–84; Educational Council: Member 1977–83; Alumni Association Alumni Activities Board Member 1981–82; MIT Club of Hartford: Director 1982–83; President 1979–82; Treasurer 1976–79; MIT Club of San Diego: Member 1974–75; Junior Achievement: Advisor and Coordinator 1975–82, Recruiter 1975–83; Greater Hartford Leadership Program 1982: Combustion Engineering Delegate



Robert A. Wofsey
S.B. 1948, Management
Director of International Accounting & Finance
Arthur Young & Company, Mamaroneck, NY

Alumni Fund Special Gifts Committee 1975–76; MIT Club of Westchester: Director 1981–84, Treasurer 1982–83; Class of 1948 Reunion Committee: Member 1968; Member: American Institute of CPA's, Massachusetts Society of CPA's, Tau Beta Pi; Pi Lambda Phi

District 8



Alice E. Cowan
S.B., S.M. 1978,
Chemical Engineering
Research Chem. Eng.,
New Process Development
JFB Technical Center,
Minneapolis, MN

Educational Council: Member 1980–83; MIT Club of Minnesota: Vice President and Program Chairman 1980–83; Member AIChE



William H. Heidtmann
Architecture, 1932
Architect (Retired)
Former Senior Partner
Gibbons, Heidtmann
& Salvador, Architects
& Planners, Englewood, CO

MIT Club of Colorado: Director 1978–83; American Institute of Architects: Fellow 1973; American Institute of Architects, Westchester Chapter: Director 1967–69, President 1970–71; White Plains, New York 1954–74: Citizens' Housing Council: Director, President; Council of Community Services: Director, President; Civic & Business Federation: Vice President–Civic Division; United Way: Director, President; YMCA: Director



Stanley Martin, Jr.
S.B. 1950, Aeronautical Engineering
Vice President
JVX Engineering
Bell Helicopter Textron, Inc.
Dallas, TX

Alumni Association Morgan Award 1982; Alumni Fund: Personal Solicitation Program 1981 and 1982; Educational Council: Dallas Regional Directors 1975–present; MIT Club of Dallas: Board of Directors 1974, President 1972–73; MIT Second Century Fund Solicitor 1961; National Research Council: Member, Aeronautics and Space Workshop on the Role of NASA in Aeronautics 1980; American Helicopter Society: Former Southwest Regional Vice President and Director; Rush Creek Yacht Club: Fleet Captain, Soling Fleet #28



Robert L. Rorschach
S.B. 1943, Chemical Engineering
Consultant, Chemical Engineering Process Tech. Corp., Tulsa, OK

Alumni Association Bronze Beaver Award 1980; Alumni Association: Board of Directors Member 1973–75, Club Advisory Board Member 1972–75; Alumni Fund: Reunion Gifts Committee Solicitor 1980–83, Regional Gifts Solicitor 1977–78, 1975–76, Regional Gifts Vice Chairman 1972–74; Alumni Council: Member 1973–75, Life Member 1980; Educational Council: Chairman 1978, Member 1961; MIT Club of Oklahoma: President 1964–65; MIT Class of 1943: Secretary 1981–83, Vice President 1973–78; Member: AIChE, ACS, NSPE, Sigma Xi; Tulsa City-County Environ. Adv. Comm.: Chairman 1967–78, Member 1967–present



Robert Noel Schulte
S.B. 1971, Management
President and Director
Nixdorff Lloyd Chain Co., Ladue, MO

Alumni Fund Personal Solicitation 1978–83, including Chairmanship; Educational Council 1977–1983; Alumni Council 1971–72; Athletic Board 1970–72; Athletic Association President 1970–71; Undergraduate Association: President 1971–72

District 9



Robert L. Blumberg
S.B. 1964, SM 1965,
Chemical Engineering
Chairman and CEO
Spectrographics Corp.,
San Diego, CA

Alumni Fund: Regional Gifts Chairman 1975–76; Educational Council: Regional Chairman 1982–83, Member 1972–83; MIT Club of San Diego: Director 1981–83; MIT Class of 1964: Vice President 1959–74; MIT Sustaining Fellows: Annual Member 1981–83; Youth Soccer Coach 1978–82



Burkhardt A. Kleinhofer
S.B. 1939, Electrical Engineering
Retired
Long Beach, CA

MIT Club of Southern California: President 1979–81, Assistant Treasurer/Treasurer 1978–79; Educational Council: Vice Chairman Los Angeles Area 1982–present, Member 1967–present; AIEEE: Past Senior Member; ASQC, AOPA, ARRL: Professional Group Secretary Los Angeles Area 1956; Awards: National Defense Research Committee 1945, Naval Ordnance Development 1945



R. Gary Schweikhardt
S.M. 1973, Management
Vice President, Chief Financial Officer
Mathematical Sciences Northwest, Inc., Seattle, WA

Educational Council: 1979–82; MIT Club of Puget Sound: Director 1980–82, President 1980–82, Treasurer 1979–80; Sloan Graduate Management Association: State Coordinator; Co-Founder and Organizing Committee for Technology Northwest Conference; Member: AEA, ASME, Delta Chi Fraternity



Paul Shepherd
S.B. 1953, Civil Engineering
President
Paul Shepherd & Associates
Consultants, Industrial & Office Parks,
San Francisco, CA

Alumni Association Bronze Beaver Award 1976; Alumni Association: Vice President 1979–81, Director 1960's; Alumni Fund: Personal Solicitation Chairman 1980–81, Special Gifts Solicitor 1977–79, Reunion Gifts Comm. Solicitor 1977–78, Fund Board Chairman 1975–77, PS Telethon Chairman 1981–82; Alumni Council Life Member 1980; Committee on Alumni Nominees to Corporation Visiting Committees: Member 1977–80; Sponsoring Committee Building 10: Member 1976; MIT Club of Northern California: Exec. Member 1979–81, Director 1977, President 1965; MIT Corporation: Member 1971–77, Corporation Visiting Committee for the School of Architecture and Urban Planning Member 1973–77, 1980–84; Corporation Visiting Committee, Department of Civil Engineering, Member 1972–77; MIT Leadership Campaign Leadership Committee 1977–80; National Association of Industrial and Office Parks: Director 1971–83, President 1975–76

Fill out the ballot to the left and return by May 14.

Sports Report

Ken Cerino



Ken Cerino is in his fourth year as director of sports information; he is currently president of the Eastern College Athletic Conference Sports Information Directors' Association (ECAD-SIDA).

Some wonderful things happened this past fall as five of eight in-season M.I.T. sports teams had winning records. Here's a quick review of the fall season.

Men's cross country: First-year coach Halston Taylor continued the winning tradition as his team posted a 4-3 record for its fifth consecutive winning season. M.I.T. finished sixth at the IC4A Championships (College Division) as Bob Walmsley, '84 (Cheshire, England), placed fourth among 113 runners. Tech also participated in the NCAA Division III Championships for the fourth straight year, finishing sixteenth among 21 teams. Paul Neves, '83, was the team captain.

Women's cross country: M.I.T. completed its second season of varsity competition with a perfect 11-0 record. Coach Christopher Lane's young squad was led by Sarah de Leon, '85, who finished thirty-ninth at the NCAA Division III regionals held in Boston. She also was first in two triangular meets. Co-captains were Theresa Sutton, '83, and Ulrika Oster, '84.

Women's field hockey: Under first-year coach Mary Ellen Martin, M.I.T. posted a 5-9 record against tough competition. Highlights were shutout wins over Western New England (4-0), Endicott (1-0), and Barrington (1-0). Karen Renaud, '84, and Elizabeth Anderson, '84, led the team in scoring with five goals apiece. Renaud and Louise Jandura, '84, served as team co-captains.

Club Football: M.I.T. improved its record to 3-5 after posting a 2-6 record last year in the strong New England Conference. Defensive back Doug Gouchoe, '83, was selected to the conference first-team all-star squad. Offensive guard Scott Berceli, '85, offensive tackle John Einhorn, '84, and linebacker Jon Opalski, '84, made the second team.

Golf: Coach Jack Barry's highly-regarded team recorded a perfect 6-0 record including wins over Division 1 ri-

vals Boston College and Northeastern. M.I.T. also finished nineteenth among 44 schools at the New England Championships. Since 1972, Tech has a combined fall/spring record of 114-79 (59.1 percent). Patrick Fowler, '83, was the team captain.

Sailing: Coach Hatch Brown's men's team competed in 20 regattas, finishing in the top five 14 times and winning the Stonehill Invitational. Top skippers were captain Bruce Klein, '83, Penn Edmonds, '83, Peter Quigley, '84, and Al Pleus, '84. The women, under coach Stu Nelson, competed in seven regattas. Michelle Bagdis, '84, finished fifteenth among 37 sailors at the New England Intercollegiate Single-Handed Championships. She and Dominique Grey, '84 (Bulle, Switzerland), were the team co-captains.

Soccer: M.I.T. posted a 3-10 record and competed in the tough Greater Boston League with Division I rivals Boston College, Boston University, and Harvard. Highlights were a pair of shutout wins over Trinity (3-0) and Tufts (1-0), and an overtime victory against Bates (2-1). Co-captains John Busa, '83, and John English, '83, each was selected to the GBL all-star team. For Busa, it was the fourth consecutive year he has made the GBL honor team. Busa also received an honorable mention on the National Soccer Coaches Association Division III all-New England team. M.I.T. coach is Walter Alessi.

Women's Tennis: Coach Candy Royer's young team fashioned a 5-6 record with wins over Bates, Clark, Emmanuel, Endicott, and Simmons. Susan Strausman, '83, was the squad's top player and team captain.

Women's Volleyball: Coach Dave Castanon's team was the *big* story last fall, reaching the quarter-finals of the NCAA Division III Tournament before losing to Sonoma State, Calif. M.I.T. was 34-5 for its best mark in eight years of varsity competition. Tech also captured the Eastern AIAW Division III Northeast Tournament title and won its fifth state tournament in the last eight years. Anella Munro, '85 (Vancouver, British Columbia), was selected to both the NCAA regional and Eastern all-star teams. Tri-captains were Margaret Kniffin, '83, Amy Smith, '84, and Barbara Wesslund, '84.

Water Polo: M.I.T. posted a fine 14-8-1 record which included two wins apiece over Yale and Columbia, and victories over Notre Dame, Harvard, and Princeton. John Friedman, '83, and George Jaquette, '85, made New England first and second all-star teams, respectively. Friedman and Peter Kalish, '83, were the team co-captains.

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Alexander W. Moffat, Jr.

Under the Domes

At the Top of the Top Ratings

M.I.T.'s place at the very top of U.S. graduate education was confirmed late last winter when the Conference Board of Associated Research Councils released results of a \$500,000 survey of scholarly opinion—a sophisticated way of tapping the continuing gossip about who is strong and who is strongest.

M.I.T. led all universities in the number of fields in which its graduate work was rated best in the nation—a total of nine: biochemistry, cellular and molecular biology, computer sciences, economics, electrical engineering, linguistics, mechanical engineering, microbiology, and physics.

In six other fields M.I.T. was placed just under top rank (the numbers indicate M.I.T.'s position in the national rankings): chemistry (4), geoscience (2), mathematics (3), chemical engineering (3), civil engineering (2), and political science (6).

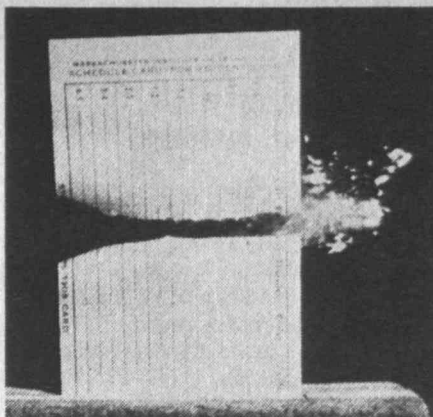
In only one of M.I.T.'s fields represented in the survey—psychology—was the Institute omitted from the top ten institutions.

Kenneth A. Smith, '58, associate provost, admitted to the *Boston Globe* what seemed obvious to everyone: "M.I.T. has just done extraordinarily well, and we take a great deal of pride in that fact." But he warned that studies of academic reputations "are so subjective that they have to be taken with some caution."

Hollomon Retires as CPA Director

Professor J. Herbert Hollomon, '40, has left the post of director of the Center for Policy Alternatives which he founded in 1972, and he'll be succeeded by Nicholas A. Ashford, associate professor of technology and policy. Dr. Hollomon, who has made a courageous recovery from the effects of a severe stroke suffered several years ago, will spend full time in teaching and research as Japan Steel Industry Professor of Engineering.

Dr. Ashford, who has been with the center since its founding and has been assistant director since 1978, was trained



"Drop day" made real. The last day to cancel registration for any course is a landmark for undergraduates—a hard story to tell with a new twist every time it comes along. But for The Tech's photo editor Laurie S. Goldman, '84, it was easy: she went to Professor Harold Edgerton's strobe lab to photograph a .22-caliber bullet cutting an official "drop card" into two useless pieces—just the way the calendar makes the card obsolete on "drop day."

in chemistry and law at the University of Chicago, where he also studied economics and business administration. He is a specialist in occupational disease and the regulation of technology, currently engaged in research on the effects of regulation on innovation in pharmaceutical, chemical, and manufacturing industries.

Rhodes Scholar

Jerri-Lynn Scofield, '83, who was editor-in-chief of *The Tech* until February, will be in Oxford next fall as M.I.T.'s only winner of a 1983 Rhodes Scholarship. She'll receive two M.I.T. degrees in June in political science (she entered the Institute expecting to study engineering), and Ms. Scofield expects to continue at Oxford in the field of political theory.

\$176,000 to Wrighton

Professor Mark Wrighton, whom one of his colleagues calls "the most impressive chemist in his age group in the world," is one of 20 new recipients of the MacArthur Foundation's no-strings-attached stipends to encourage creativity. Professor Wrighton's grant is for \$176,000, and he wants to use it for "something special—a really new direction." Professor Wrighton's work to date has been in the fields of metal catalysts and photochemistry—the search for a chemical process to utilize solar energy.



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**Carroll L. Wilson, 1910-1983:
Outstanding Manager of Technology**



C. L. Wilson

Carroll L. Wilson, '32, Mitsui Professor in Problems of Contemporary Technology, Emeritus, who had been a member of the M.I.T. faculty since 1959 and a distinguished student of technology and its management since before becoming the first general manager of the U.S. Atomic Energy Commission in 1947, died in Providence, R.I., January 12. A victim of leukemia, he was 72.

At the time of his death Professor Wilson was director of the European Security Study, a privately financed assessment of the potential for improving the conventional defense capabilities of the NATO nations. This work will be continued by Professor Wilson's colleagues, with a report due later this spring.

The European Security Study was the latest in a series of international inquiries organized by Professor Wilson in the 1970s on world environmental and technical problems—man's impact on the global environment, inadvertent climate modification, energy prospects, alternative energy strategies, and coal utilization. Howard W. Johnson, chairman of the M.I.T. Corporation, said that through these projects Professor Wilson had "influenced for the better both policy and research priorities in many countries. But perhaps his major contribution," said Mr. Johnson, "was the imaginative method he developed for tackling monumental problems . . . bringing together people from varied points of view in the joint approach to complex global situations."

Professor Wilson remained at M.I.T. for several years after receiving his undergraduate degree in business and engineering administration and then took government assignments in the field of technology policy culminating with his role as general manager of the AEC. Later he had major responsibilities in Climax Uranium Co. and Metals and Control Corp. before returning to M.I.T. as a lecturer in the Sloan School of Management in 1959. Thereafter, in addition to his leadership of worldwide studies of major technical-social issues, Professor Wilson conceived and directed an M.I.T. Fellows in Africa Program, helped establish the International Centre for Insect Physiology and Ecology in Nairobi, and helped plan the first United Nations Conference on Human Environment in

Stockholm (1972). Outstanding among many honors was the 1982 John and Alice Tyler Ecology/Energy Prize of \$100,000.

Paul V. Cusick, 1917-1982

Paul V. Cusick, who rose through a 34-year career at M.I.T. to become a national leader among research university business officers as the Institute's vice-president for fiscal relations, died on December 15 at Massachusetts General Hospital of complications following surgery. He was 65.

Mr. Cusick joined M.I.T. in 1944 as chief accountant in the Division of Industrial Cooperation which administered the Institute's fiscal relations with industry and government research sponsors. He had studied accounting at Bentley College. By 1957 he was comptroller of the Institute and in 1970 became vice-president responsible for all fiscal relations with government, industry, and other universities.

Howard W. Johnson, chairman of the Corporation, described Mr. Cusick as "one of the principal architects of the arrangements which have provided the financial support that has made possible the flowering of American science over the last three decades."

Following retirement from M.I.T. in 1978 Mr. Cusick served as vice-president and treasurer of the Northeast Solar Research Institute; he was for many years a principal member of the Committee on Governmental Relations of the National Association of College and University Business Officers.

Frederick E. Terman, 1900-1982

Frederick E. Terman, Sc.D.'24, emeritus provost of Stanford University who was widely recognized as academic architect of Silicon Valley, died of cardiac arrest at his home in Palo Alto, Calif., on December 19; he was 82.

Dr. Terman came to M.I.T. from Stanford in 1922 to study with the late Vannevar Bush, '16; he returned to Stanford with his new degree in 1924, rose to become dean of engineering in 1946 when he returned after World War II service at Harvard, and was provost starting in 1955. Upon retiring ten years later, he declared that "if I could relive my life, I believe I couldn't do better than play the same record over again."

Deceased

Ichabod F. Atwood, '03; January 17, 1983; 279 High St., Topsfield, Mass.
Kurt Roehrs, '09; April 12, 1972; 649 Franklin Lakes Rd., Franklin Lakes, N.J.
Harold D. Mitchell, '12; December 21, 1982; 30 Williamstowne Ct. #12, Cheektowago, N.Y.
Frederick W. Lane, '13; November 19, 1982; 37 E Lee St., Bel Air, Md.
Long Lau, '14; February 21, 1982; 654A North

Kuakini St., Honolulu, Hawaii.
Bernard Landers, '15; January 17, 1983; 280 Boylston St., Chestnut Hill, Mass.
Ferdinand John Kruse, '17; May 16, 1982; 629 SE 19th Ave., Deerfield Beach, Fla.
Ronald B. Brown, '18; March 30, 1982; 145 Ordale Blvd., Pittsburgh, Penn.
William G. Coke, '18; December 30, 1977; Auburn, Ky.
Rolf Knudsen, '18; October 1982; Borgestad 3900, Porsgrunn, Norway.
James E. Longley, '18; November 15, 1982; 29 Fox Chase Rd. East, Woodland Hills, Asheville, N.C.
Robert B. Swain, '18; November 20, 1982; 1 Constitution Plaza, c/o Rieye, Hartford, Conn.
George Whittier Spaulding, '21; November 29, 1982; 3737 Village Green Dr., Sarasota, Fla.
Herman B. Thompson, '21; October 19, 1982; 674 North 59th St., Omaha, Neb.
Walter Dietz, '23; June 30, 1982; 2220 S Ocean Blvd. Apt. 1103, Delray Beach, Fla.
G. Fred Ashworth, '24; December 7, 1982; 1840 N Prospect Ave. #808, Milwaukee, Wisc.
Chester A. Boggs, '25; November 13, 1982; 5288 Avenida Del Sol, Laguna Hills, Calif.
Henry Doble, '25; November 1982; PO Box 7443, San Francisco, Calif.
E. Willard Gardiner, '25; December 13, 1982; 53 Foster St., Cambridge, Mass.
Alban J. Lobdell, '27; November 18, 1982; 645 Pearl Ave., Kirkwood, Mo.
Lester N. Woolfenden, '27; December 28, 1982; 250 Pecan Dr., Paducah, Ky.
Stanley M. Humphrey, '28; September 18, 1982; 1242 Woodcrest Circle, Bloomfield Hills, Mich.
Richard F. Piper, '28; January 6, 1981; Rice Rd., Sudbury, Mass.
George Grier Kirkpatrick, Sr., '29; June 17, 1982; PO Drawer K, Gainesville, Fla.
Myron W. Ryder, '29; 1981; 73401 Salt Cedar, Palm Desert, Calif.
Edward P. Dean, '30; June 13, 1981; 449 Grace St. Apt. C, Greenwood, S.C.
Frederic B. Stanley, '31; September 15, 1982; 5119 Ridgewood Ave., Daytona Beach, Fla.
Carroll L. Wilson, '32; January 12, 1983; 130 Jacob St., Seekonk, Mass.
Manly M. Windsor, '32; December 7, 1982; 5579 East Lake Rd., Sheffield Lake, Ohio.
R. Barlow Smith, '33; December 19, 1980; c/o Martin Wilson, 222 Market St., Lewisburg, Penn.
B. Russell Franklin, '34; January 1, 1983; 5661 Begonia Rd., Venice, Fla.
Israel Nigrosh, '34; October 18, 1982; 90 Brighton St., Belmont, Mass.
Norman A. Cocke, Jr., '36; December 11, 1982; 304 Pine Needle Dr., Myrtle Beach, S.C.
Sebastian G. Mazzotta, '36; September 15, 1982; 5 Mazzotta Pl., Middletown, Conn.
Sidney Sussman, '37; October 27, 1982; 82 Laurel Ledge Rd., Stamford, Conn.
Arthur B. Sperry, '38; February 17, 1982; 2315 New Bern Ave., Raleigh, N.C.
Lyle M. Richardson, Jr., '41; December 4, 1982; PO Box 1466, Conway, N.H.
Royal K. Joslin, '46; April 10, 1982; c/o R.D. Joslin, 219 Church St. #4, Philadelphia, Penn.
Harry L. Cavanagh, '47; August 26, 1982; 5611 Wycliffe Rd., Vancouver, BC, Canada.
Jack C. Kiefer, '47; August 10, 1981; The Estate of Jack C. Kiefer, 629 Highland Rd., Ithaca, N.Y.
Tsuruzo Takeda, '50; July 27, 1982; 1744 West Broad St., Bethlehem, Penn.
Keith R. Johnson, '52; August 10, 1982; 5447 Woodlawn Blvd., Minneapolis, Minn.
Donald W. Steel, '53; May 20, 1982; Rogers Rd., Gates Mills, Ohio.
Joseph S. Gaziano, '56; December 17, 1982; Plummer Rd., Epping, N.H.
James E. Cunningham, '57; January 12, 1983; 4144 San Carlos Dr., Dallas, Tex.
Henry T. Inman, '57; August 3, 1982; 113 Hillside Rd., Wayne, Penn.
Otto H. Poensgen, '59; October 29, 1982; Petersbergstrasse 9, D6600 Saarbrücken, W. Germany

Courses

Civil Engineering

Frederick P. Salvucci, '61, who was secretary of transportation in the Massachusetts administration of Governor Michael S. Dukakis in 1975-79, is back in the State House—same job, same governor. In the four years between Governor Dukakis' two terms, Mr. Salvucci was research associate in the department at M.I.T., working on policy issues in the Transportation Systems Division.

Saturnino Suarez-Reynosa, S.M.'76, reports, "During the year 1981 I was project manager for offshore construction in the bay of Campeche for ICA (my employer), a construction company. We laid 42 km of 48-inch pipe and 25 km of 36-inch pipe, and installed two loading buoys for crude oil tankers. This year I was transferred to the Industrial Construction Division as administrative manager of ICA International, another construction company." ... **John B. Scalzi**, Sc.D.'40, writes, "I am a program director at the National Science Foundation, supporting research projects on earthquake engineering. My principal area of interest is in the field of experimental research on buildings and bridges." ... **Peter Likins**, S.M.'58, president of Lehigh University, has been elected a member of the National Wrestling Hall of Fame. He was selected for the Hall of Fame's "Career Corner," a special division in the wrestling museum for men who not only excelled in wrestling but also are excelling in their career and life after graduation from college." ... **Douglas H. Merkle**, Ph.D.'71, assumed the position of technical director of Applied Research Associates on October 1, 1982. He describes ARA as "a civil engineering research firm specializing in soil, rock, and structural dynamics, with offices in Albuquerque, N.M., Washington, D.C., Raleigh, N.C., and South Royalton, Vt."

Forrest N. Krutter, S.M.'76, has been promoted from assistant general attorney to general attorney at Union Pacific Railroad Co., Omaha, Neb. ... **Ross B. Corotis**, Ph.D.'67, professor and head of the civil engineering program at the John Hopkins University, Baltimore, Md., has been named the Willard and Lillian Hackerman Professor of Civil Engineering. ... **Lloyd A. McCoomb**, S.M.'70, writes, "I have been in the transportation area for several years. I am now senior development officer of current technology at the Transportation Development Centre, Transport Canada. In the spring of 1982, I received a Ph.D. from the University of Toronto, where my dissertation entitled 'Simplified Urban Transportation Planning Procedures Using Census Data,' was awarded first prize in an annual competition sponsored by the Canadian Transportation Research Forum. I am also teaching part-time in the engineering faculty of McGill University, Montreal." ... **Alonso E. Rhenals**, S.M.'74, reports, "After spending four years in Colombia as director of a multipurpose water resources project

and then as director of the Center for Research of Universidad del Norte in Barranquilla, I came back to M.I.T. to work as research associate in the Water Resources and Hydrodynamics Laboratory. Currently, I work for the Analytic Sciences Corp. (TASC), Reading, Mass., as a member of the professional staff.

Joseph R. Brennan, S.M.'31, an engineering consultant with the U.S. House of Representatives Public Works Committee from 1957 to 1968, passed away on November 5, 1982. Prior to joining the Public Works Committee, he was a civil engineer with the Army Corps of Engineers. ...

Vincent J. Roggeveen, S.M.'53, of Los Gatos, Calif., passed away on September 25, 1981. He was a member of the department staff and later faculty at M.I.T. from 1951 to 1959, when he joined the faculty in transportation planning at Stanford; no further details are available.

Mechanical Engineering

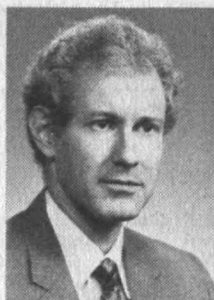
Larry M. Sweet, Ph.D.'74, has joined the General Electric Research and Development Center, Schenectady, N.Y., as manager of the Control Theory and Systems Program. Prior to this, he was a faculty member in the Department of Mechanical and Aerospace Engineering at Princeton University.

Professor **John C. Chato**, Ph.D.'60, has been reappointed chairman of the Executive Committee of the engineering faculty at the University of Illinois, Urbana-Champaign. ... **Juan J. Manzano-Ruiz**, Ph.D.'81, writes, "I joined INTEVEP S.A., a research-oriented company in the Venezuelan petroleum industry, in October 1981. Presently, I head the energy group whose main projects include: two-phase flow (steam/water) in horizontal- and vertically-downward pipes of large dimensions, alternative ways of producing steam for enhanced oil recovery, cogeneration concepts, modelling energy flows in steam plants, and studies on fuel alternatives (petroleum coke, residuals, etc.). Also, I teach undergraduate courses (fluid mechanics and energy conversion) and one graduate course (design of thermal systems) in two universities in Caracas." ... **Anthony C. Lunn**, Sc.D.'72, is currently working in the field of suture research and development at Ethicon, Inc., Somerville, N.J.

Emmett E. Day, S.M.'45, was recently elected fellow in the Society for Experimental Stress Analysis. The award was presented at the 1982 spring meeting in Hawaii. ... **Blake D. Mills, Jr.**, S.M.'35, writes, "As a 1977 retiree as a mechanical engineering professor at the University of Washington, I now go there 'to improve my mind at no cost to the taxpayers.'" ... **Alfred G. Peron**, S.M.'75, writes that he would like to receive articles on software, computers, operating systems, artificial intelligence, and future trends of computer architecture (fifth generation computers, etc.). ... **Lawrence D. Blackman**,



F. N. Krutter



L. M. Sweet

S.M.'81, reports that he is a member of the technical staff at Rockwell International Space Transportation and Systems Group, Downey, Calif., and is currently involved in dynamic analyses of the space shuttle hydraulic flight control system. He is also performing independent research and development on nonlinear control system optimization and is the author of papers on frequency analysis of the space shuttle thrust vectoring system and MHD arcing.

Webster L. Benham, S.M.'77, writes, "I recently joined the Benham Group, Vienna, Va., as a project mechanical engineer. The Benham Group is a nationally recognized architectural-engineering firm, with considerable credentials in the design of energy recovery systems for industrial, institutional, and commercial facilities. My grandfather founded the company in 1909." ...

Carl C. Hiller, Ph.D.'76, reports that he is employed by Acurex Corp., Mountain View, Calif., where he is responsible for mechanical design aspects of large-scale solar electric generating plants, industrial process heat installations, and combined-cycle cogeneration power plants for industrial users.

Curt E. Hoerig, '38, of Wauwatosa, Wis., passed away on October 7, 1980; no details are available.

Materials Science and Engineering

William F. Hosford, Sc.D.'59, professor of metallurgical engineering at the University of Michigan, is co-author (with his colleague Professor Robert M. Caddell) of *Metal Forming: Mechanics and Metallurgy* (Prentice-Hall, Inc., 1982). The text emphasizes the importance of the interaction between tooling and metal during plastic forming and the interrelationship of the process and the metal being processed, according to the publisher.

Samuel K. Nash, Sc.D.'48, is currently a lecturer in the Engineering Department at Drexel University. ... **Winston W. Liang**, Sc.D.'76, formerly with Standard Oil Co. (Indiana) is now with Gas Research Institute. "My current responsibility is project management in the area of materials science and engineering," he writes. "Project areas include: structure properties relationship in polyethylene gas piping materials, high-temperature materials in gas-fired systems, and others." ... **George L. Durfee**, '54, has been named manager of melt operations for the Aluminum Melt Facility and the new Aerospace Alloys Center at the Wyman-Gordon, Co., Millbury, Mass. ... **Richard E. Cole**, S.M.'52, writes, "I have retired from Reynolds Metals Co., where was I employed since graduation from M.I.T."

Jozef F. Graczyk, Ph.D.'68, a member of the IBM Thomas J. Watson Research Center since 1971, passed away on January 29, 1982. At IBM

since 1971, Dr. Graczyk made important contributions in research on the structure of amorphous silicon, germanium, and metallic alloys. He published 28 scientific papers (between 1969 and 1981). . . . **Themistocles Floridis**, Sc.D.'54, professor of materials engineering at Virginia Polytechnic Institute and State University, passed away on September 30, 1982.

IV

Architecture

E.A. Glendening, M.Arch.'54, writes, "In 1982 I was for the first time listed in *Who's Who in America*, after being listed in *Who's Who in the Midwest* since 1972." . . . **Craig D. Roney**, M.Arch.'71, is now a partner in the architectural firm of Rafferty, Rafferty, Mikutowski, Roney & Associates, St. Paul, Minn. . . . **George A. Skiadaressis**, M.Arch.'53, is currently a professor in the School of Engineering at the National Technical University of Athens and is also in private practice in architecture and planning.

Richard Warren Smith, M.Arch.'66, reports, "After working for various architecture and planning firms on the east and west coasts, I received a master's degree in planning from UCLA and a Ph.D. in architecture from the University of California, Berkeley. In 1974 I formed and currently head my own firm, R.W. Smith & Associates, Oakland, Calif. I am also the founder and president of the Environmental Research and Design Group, a non-profit corporation." . . . **Anthony Tappe**, M.Arch.'58, president of A. Anthony Tappe Associates, a firm of architects and planners providing design and consulting services to clients in the United States and abroad, has been installed as president of the Boston Society of Architects at its recent annual meeting. . . . **Maurice Childs**, M.Arch.'60, a founding partner of CBT/Childs Bertman Tseckares and Casendino, Inc., Boston, has been appointed to the M.I.T. Corporation Visiting Committee of the M.I.T. School of Architecture and Planning.

Graeme M. Aylward, M.C.P.'66, a faculty member of the Department of Architecture at Plymouth Polytechnic, Plymouth, England, passed away on August 27, 1982.

V

Chemistry

Paul K. Davis, Ph.D.'70, is currently a program director for the Rand Corp.'s Strategy Assessment Center and was previously a senior executive in the Office of the Secretary of Defense. . . .

Richard P. English, Ph.D.'70, is currently manager-technical services and product assurance at Applied Materials, Inc., Santa Clara, Calif. . . . **Philip Selwyn**, Ph.D.'70, who has been chief scientist of the Navy's Ballistic Missile Submarine Security Technology Program, has joined Honeywell as part of the President's Exchange Program. He'll serve for one year as special assistant to Honeywell's vice-president for science and technology, assessing how well Honeywell's technology development efforts contribute to the company's corporate and divisional goals, then will return to his former Navy assignment.

Harold F. Stedman, S.M.'60, of West Roxbury, Mass., passed away on February 27, 1982; no details are available.

VI

Electrical Engineering and Computer Science

Professors **Alan V. Oppenheim**, '59, and **Alan S. Wilksy**, '69, are co-authors (with **Ian T. Young**, '65) of a new textbook designed for an undergraduate course in *Signals and Systems*

(Prentice-Hall, Inc., 1983). The concepts are of "fundamental importance in all engineering disciplines," write the authors in their preface, and a course in the subject "can be one of the most rewarding, exciting, and useful courses that engineering students take."

John A. Tucker, director of the VI-A Program, reports Christmas greetings from **David M. Breuer**, '74, and **Kenneth A. Van Bree**, '71. Dave is with Hughes Aircraft Co., Los Angeles, where he is a section manager with the Radar Systems Group; he is one of Hughes' recruiters at M.I.T. Ken is a member of the research staff at Hewlett-Packard Laboratories, Palo Alto, where he is involved in the VI-A selection process for H-P.

Robert L. Lagace, '60, senior staff member at Arthur D. Little, Inc., Cambridge, was a recent visitor to the Institute.

Twelve members of the M.I.T. community figured in *Computer Design* magazine's selection of a Computer Industry Hall of Fame late last year. Five were listed as computer design pioneers: **C. Gordon Bell**, '56, vice-president for development and engineering at Digital Equipment Corp.; **Robert N. Noyce**, Ph.D.'53, founder of Intel Corp.; **Kenneth H. Olsen**, '50, president of Digital Equipment Corp.; **Ivan E. Sutherland**, Ph.D.'63, cofounder of Evans and Sutherland Computer Corp.; and **Kenneth L. Thompson**, '68, of Bell Telephone Laboratories (co-author of the UNIX operating system). Among runners-up: Professor **Fernando J. Corbato** of M.I.T. (builder of the first time-sharing system); **Thomas Horgan**, '50, of Inforex (pioneer of commercial key-to-disk entry); **Alan Kay**, '48, of Xerox (for simplifying the man-machine interface); Professor **Leonard Kleinrock**, Ph.D.'63, of the University of California at Los Angeles (for packet switching technology); **Raymond C. Kurzweil**, '70, of Kurzweil Computer Corp.; Professor **Seymour Papert** of M.I.T. for educational applications; and **Lawrence G. Roberts**, '59, president of GTE Telenet.

Professor **Herbert H. Woodson**, '51, director of the Center for Energy Studies of the University of Texas in Austin, has completed his service as chairman of the Committee on Magnetic Fusion of the National Research Council. The committee's goal was to stimulate interest of the U.S. engineering community in magnetic fusion; among the major conclusions of the workshop which was the committee's principal activity: "substantial technology development" is required—a sustained research and development program throughout the period required to develop commercial applications of fusion.

The Henry Ellis Warren Professorship, established by a \$1 million gift to M.I.T. from the Warren Benevolent Fund, has been assigned to **Louis D. Braida**, Ph.D.'69, whose work on speech and hearing aids for the deaf and deaf-blind has won national attention. The late Mr. Warren, who was a member of the M.I.T. Class of 1894, is known as "the father of electric time" for his invention of the first accurate and practical electric clock. But his work may have had more significance in the management of electric generating equipment.

William F. Hederman, S.M.'71, writes, "I am a project manager at ICF in Washington. I will be serving on the satellite economic assessment working group preparing for the World Administrative Radio Conferences in 1985 and 1987." . . .

Roger R. Schell, Ph.D.'71, reports that he has been promoted to colonel, U.S.A.F., and appointed deputy director of the DOD Computer Security Evaluation Center, Ft. Meade, Md. The center evaluates the security of commercial and government computer systems and manages a consolidated program of generic computer security research and development in the Department of Defense.

Eberhard F. Wunderlich, Ph.D.'75, has been recently appointed head of the Systems Planning Department at American Bell, Inc. . . . **David L. Kleinman**, Ph.D.'67, writes, "I am continuing my activities at the University of Connecticut and at Alphatech, Inc., on mathematical and empirical modeling of human decisionmaking." . . . **George**

W. Dupree, S.M.'39, reports, "I retired on November 30, 1982, after 37 years with Southwestern Public Service Co., Amarillo, Tex., and 43 years in the electric utility business (vice-president—rates and budgets, 1962-67; vice-president—operations, 1967-77; and vice-president—management systems 1977-82)."

Winthrop M. Leeds, '39, writes, "Since losing my wife in March, I have decided to move into a new life care community called Sherwood Oaks, just north of Pittsburgh, Penn. I am permitted to take my dog Buster and install my home radio station N3BIZ. Recently I was appointed to the IEEE National History Committee." . . . **Terrance R. Bourk**, S.M.'70, reports that he joined Linkabit in July 1981 as senior engineer. . . . **Oleg V. Fedoroff**, S.M.'63, writes, "I am now a senior engineer with IBM's Federal Systems Division, Gaithersburg, Md., having left the BDM Corp. after 15 years and as an assistant vice-president."

Dean A. Powers, '51, who recently retired as administrative officer of the M.I.T. Electric Power Systems Engineering Laboratory, passed away on November 11, 1982. He had been at M.I.T. since 1949, joining the research staff and becoming assistant in the executive offices of the department in 1966. From 1966 until joining EPSEL in 1978, he was associated with the department's Facilities Office.

VI-A Program

By the time this article appears, we'll have gained an idea of how this country's current economic climate is affecting our VI-A Program this year. Several companies who've already spoken to us (January) say they will not be able to select any new VI-A students, their budgets only allowing them to provide assignments for those continuing with them. Others have said they will reduce their number of offers.

This deepening recessionary trend leads to the prediction that a larger percentage of students will seek employment via the VI-A Program than heretofore. Noting that this year's sophomore class in Course VI is 3.6 percent larger than last year's, even a modest increase in applicants to, say, 56 percent (up from last year's 53 percent) will mean 205 applicants this year (compared to our previous high of 196 in 1981).

Being added to the program this year is the General Electric Co.'s Microelectronics Center located in Research Triangle Park, Raleigh/Durham, N.C. This new facility will be filling a slot vacated by GE's E-Labs, Syracuse, N.Y. Mark B. Baron has transferred from Syracuse to head up the new center and will bring his familiarity with and support of VI-A with him. Our students will be under the direct supervision of L. Keith Russell, manager of Circuit design, with whom Director Tucker has met several times in planning sessions. Since General Electric is a major supporter of the department's ongoing VLSI Program, joining VI-A provides an additional tie which will strengthen this new area of instruction and provide practical experience for Course VI students via VI-A.

While on a visit to GE's Microelectronics Center in November, John Tucker happened to meet **James T. Carlo**, '68, while having breakfast at the Governor's Inn, Raleigh, N.C. Jim is with Texas Instruments, Inc., Houston, Tex.

In the January 1983 'VI-A Notes' the name of **Melvin M. Weiner**, '55, was inadvertently omitted from the list of those VI-A's who've been on-campus interviewing for their companies. Mel was interviewing in October 1982 for MITRE Corp. and he, **Johnny Low**, '78, and Director Tucker had an enjoyable luncheon reunion at M.I.T.'s Faculty Club. Mel is past president of the Boston Alumni Chapter of Eta Kappa Nu and headed up their Motor Vehicle Safety Committee.

More recently **Donald D. Weiner**, '56 (Mel's brother), visited John Tucker to discuss updated details of the VI-A Program. Don is associate dean of engineering at the University of Syracuse.

He has been put in charge of establishing a cooperative-type program there similar to M.I.T.'s and R.P.I.'s. His own VI-A experience provides a wonderful background, and he was very appreciative of the assistance rendered by the VI-A Office.

Paul L. Penfield, Jr., '60, brought back business cards to John Tucker from two VI-A's he met at a meeting of the Northern California Alumni Chapter in San Francisco this past September. **Richard M. Stern**, '77, is with Dialogic Systems Corp., Sunnyvale, Calif., and **Rosanne H. Wyleczuk**, '78, is with Hewlett-Packard Co.'s Technical Computer Group, Cupertino, Calif.

Returning to the East Coast after about nine years with Hewlett-Packard's operations on the West Coast is **Mark S. Linsky**, '72. Mark is now director of operations for Digital Systems Associates and has a new office in Kendall Square, Cambridge, Mass. He came by for a visit with John Tucker early this past January.

While in Sarasota, Fla., on vacation over Thanksgiving, Mr. Tucker called **Eugene W. Boehne**, '28, former director of the VI-A Program (1947-1960) but found him away. In December during a Christmas visit to the Boston area to be with his family, Professor Boehne reciprocated with a luncheon date at the M.I.T. Faculty Club with Director Tucker. A great time was had reminiscing about 'old times' in managing VI-A.

A note from **Edward C. Gialmo**, '74, tells us he is still living in Seattle, Wash., but since last July has been employed by Zetron, Inc., Bellevue, Wash., where he is in charge of engineering.

A number of Christmas cards came from VI-A alumni: **William R. Bidermann**, '76, working for H-P Labs, Palo Alto, Calif.; **Eric D. Black**, '77, working in San Francisco; **Geoffrey J. Bunza**, '74, working for Genrad, Inc.; **John F. Cooper**, '74, working for Dolby Labs, San Francisco, Calif.; **E. Thomas Craig**, '81, living in Sunnyvale, Calif., and working for Rolm Corp., Santa Clara, Calif.; **Bradford E. Hampson**, '75, working for PRIME Computer, Inc.; **Michael A. Isnardi**, '82, completing his VI-A graduate assignments at Bell Labs, Holmdel, N.J.; **David E. Meharry**, '71, and **Andrew E. Moysenko**, '72, both working for Sanders Associates' Microelectronic Center, Nashua, N.H.; **Eduardo H. Moncada**, '78, living in Eagle Pass, Tex.; **H. DuBose Montgomery**, '71, with Menlo Ventures, Menlo Park, Calif.; and **Eric A. Slutz**, '74, with H-P Labs., Palo Alto, Calif.

Finally, other than those mentioned earlier, the following VI-A's have visited the VI-A Office since our last writing: **David W. Duehren**, '80, with Teradyne, Boston, Mass.; **Andrew J. Eisenberg**, '79, with Honeywell, Billerica, Mass.; **Steven D. Krueger**, '79, with Texas Instruments, Inc., Dallas, Tex.; **Gary K. Montress**, '69, with United Technologies Research Corp., Hartford, Conn.; and **David K. Murotake**, '75, with RCA, Nashua, N.H.—John A. Tucker, Director, VI-A Program, Room 38-473, Cambridge, MA 02139

VIII

Physics

A portrait of **Shirley Jackson**, Ph.D.'68, commissioned by CIBA-Geigy is now among the M.I.T. collection of paintings of well known alumni. She was selected for the company's "exceptional Black scientist" series "not only for her work as a condensed matter physicist, but also for her commitment to encouraging minority students to pursue studies in mathematics and physics." As a student she co-founded the Black Student Union and served on the Task Force on Educational Opportunity.

Michael Schulz, Ph.D.'67, senior scientist in The Aerospace Corp.'s Space Sciences Laboratory, Los Angeles, Calif., has earned the 1982 Trustees' Distinguished Achievement Award, the highest honor presented to employees at the firm. He was recognized for developing a theory widely upheld as the correct interpretation to describe

the structure of the interplanetary magnetic field. . . . **David A. Smith**, Ph.D.'80, is currently group leader of ring laser gyro research at Singer, Little Falls, N.J. . . . **Jerry L. Macon**, S.M.'66, is currently president of Macon Software, Inc., a developer of microcomputer software. He has co-authored DB Master, a filing system for Apple II computers, and is sole author of DB Master for IBM microcomputers.

William G. Guindon SJ, Ph.D.'38, writes, "Since my last notes, I have been appointed a special assistant to the provincial superior of the Jesuits in New England (a post I once held, 1968-74). My duties are varied, with a number of different administrative tasks to carry out. I guess you could call me a "go-fer" mostly in personnel areas. It's fun—I set my own hours and get to see a lot of friends and acquaintances. It's a kind of genteel retirement!!" . . . **James E. Brau**, S.M.'70, has assumed the position of associate professor of physics (September 1982) at the University of Tennessee, Knoxville.

H. Henry Stroke, Ph.D.'52, will be spending a sabbatical year from New York University as scientific associate at CERN, Geneva, Switzerland. . . . **Denis W. Readey**, Sc.D.'62, became chairman in the Department of Ceramic Engineering at Ohio State University on July 1, 1982.

X

Chemical Engineering

Ralph Landau, Sc.D.'41, founder and (until last year) chairman of the Halcon SD Group, Inc., has important new roles in two West Coast educational institutions. He's now a member of the board of trustees of California Institute of Technology. And during the next four years he will give \$1 million to the Center for Economic Policy Research at Stanford University for a new study of the sources of technological innovations and their impact on American life. Dr. Landau already holds posts as consulting professor in both chemical engineering and economics at Stanford, and he finds Stanford's location in Silicon Valley a natural one for a study of how economic policies can effect technological innovation.

James C. Wei, Sc.D.'55, head of the department at M.I.T., has been honored by election to the Academia Sinica, the highest academic institution in the Republic of China, and to the American Academy of Arts and Sciences.

Robert F. Latimer, '46, reports, "My wife and I continue trying to get people into the permanent collection of the National Portrait Gallery: Vilhjalmur Stefansson, Arctic explorer (in 1980), and Mari (Marie) Sandoz, historian of the Great Plains (in 1982). For 1983 we are working for: Willa Cather, novelist, and Carl Ben Eielson, Alaska, Arctic and Antarctic pioneer flier/explorer (with G. H. Wilkins). I am still working full-time as a consulting cryogenic and chemical engineer." . . . **David S. Hacker**, S.M.'50, is presently a staff research engineer at Amoco Chemicals Corp. in research and development.

Richard N. Lovett, S.M.'43, is presently employed by Mobil Research and Development Corp. and became chairman-elect of the South Jersey Section of the American Chemical Society.

. . . **Chong Y. Yoon**, Sc.D.'59, has been named vice-president—chemical division and director—fine chemicals, of the Upjohn Co., Kalamazoo, Mich. He joined the Upjohn Co. in 1950 as a junior scientist and received the Upjohn Award for Distinguished Service in 1969.

Edward G. Spinks, S.M.'41, of Indianapolis, Ind., passed away on May 25, 1982; no details are available.

XI

Urban Studies and Planning

Proposition 2½: Its Impact on Massachusetts, a

R & D for Productivity

Can alternative research and development policies revitalize American productivity?

Four answers will come to the M.I.T. Alumni Center of New York at an evening conversation on April 28 between William Norris, founding chairman of Control Data Corp.; Edward D. David, president of Exxon Research and Engineering Co.; and Professors Edward B. Roberts and James Utterback of M.I.T. For information and reservations: (212) 532-8181.

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Upon completion of his second volume on the history of M.I.T.'s Geology Department, Robert Shrock, Professor Emeritus, proudly receives from Frank Urbanowski, director of the M.I.T. Press, hand-bound copies of *Geology at M.I.T.: 1865-1965*. Mrs. Shrock is at the left.

500-page report from the department's Impact: 2½ Project, has now been published by Oelgeschlager, Gunn and Hain Publishing Co., Cambridge (cloth \$25, paper \$15). The book contains a summary of employment and expenditure trends before adoption of Proposition 2½, the Massachusetts tax-cap referendum, and detailed reports on the strategies cities and towns have used since then to cope with the tax limitation. Professor **Lawrence Susskind**, Ph.D.'75, project director, is editor, with **James Serio**, project coordinator, as co-editor; some 25 authors' work is represented.

Dietrich Garbrecht, M.C.P.'70, reports that he has been (since 1980) a free-lance urban planning consultant and (since 1982) part-time editor of the Swiss architecture journal. In May 1981 he published *A Plan for Living in the City*; in 1982 he lectured at the Streets Institute at the University of Seattle, Wash. and later was awarded second prize in the national competition of the Swiss Designers' Association "Oeuvre" (1982). . . . **Tomasz Sudra**, Ph.D.'72, writes, "After two years on the U.N. Experiment on Urban Systems in North-eastern Mexico, I am currently a professor at ITESO teaching and directing policy research on low-income settlements and low-cost housing. I am also a staff planner of the Ministry of Human Settlements and Public Works Center in Guadalajara, Mexico, and serve as an advisor of several urban and regional planning programs in this part of the country. My wife is also teaching at ITESO in the Psychology Department."

XII

Earth and Planetary Sciences

Professor **Robert L. Huguenin**, Sc.D.'72, of the University of Massachusetts made headlines this last winter by speculation that olivine-rich meteorites found in Antarctica in 1978 originated in Mars. The idea derives from Dr. Huguenin's observation that olivine is "the most abundant mineral in some of the more ancient terrain on Mars," and it's supported by spectrographic analyses of meteorites and Martian soil at Harvard and the University of Tennessee. The proposal is that an asteroidal impact on Mars might have released material into space.

William F. Brace, Ph.D.'53, Cecil and Ida Green Professor of Geology, succeeded **Carl Wunsch**, Ph.D.'67, as chairman of the department when the latter requested leave at the end of school year 1980-81 to spend a year of research at Cambridge University. Brace is making a special effort to interest more undergraduates in preparing for careers in the earth or planetary sciences. **Martin J. Buerger**, '25, Institute Professor and Professor of Mineralogy and Crystallography, Emeritus, is as active as ever, currently writing the manuscript for this 13th book, *Image Space*. His most productive student, **Leonid V. Azaroff**, Ph.D.'54, already has seven books on crystallography and related subjects to his credit. . . . **Pat-**

rick M. Hurley, Ph.D.'40, Professor of Geology, Emeritus, and wife Margaret now spend summers in New Hampshire and winters in a condominium on Marco Island, Fla. Although Pat retired from the Institute in 1977, he continues to give public lectures and recently published the short book *Living With Nuclear Radiation* previously reported in this space.

Bruce C. Murray, '53, for the past seven years director of the Jet Propulsion Laboratory at Caltech, resigned in mid-year to take a year's leave to travel and write. It is expected that he will resume his professorship in Caltech's Division of Geological and Planetary Sciences in due course. The latest of his four books on space science is *Earth-like Planets: Surfaces of Mercury, Venus, Earth, Moon, Mars* co-authored with M. C. Malin and Ronald Greeley (W. H. Freeman and Co., 387 pp., 1981).

Edward B. Walker III, '46, became the new president and chief operating officer at Gulf Oil Corp. on December 1, 1982. He joined Gulf in 1947, after completing his S.M. degree at M.I.T., and had served in various positions overseas and in the states before becoming an executive vice-president in 1978. His most recent position was president of Gulf's Energy and Minerals Co. unit. He maintains a close relationship with the Institute as a member of the Corporation Development Committee.

Nobukazu Nilzekei, Ph.D.'57, writes that he is now director of the Electrical Communication Laboratory for Nippon Telephone and Telegraph Publishing Co., Japan. . . . **Lloyd R. Breslau**, '59, formerly oceanographic scientist, U.S. Coast Guard Research and Development Center, Groton, Conn., recently assumed the position of technical director of the Army's Cold Regions Research and Engineering Laboratory, Corps of Engineers, Hanover, N.H.

The May Newsletter of the U.S. Geological Survey reported that **Robert L. Wesson**, '66, was appointed assistant director for resource programs, after serving nearly two years as assistant director for research, and that **Bruce A. Hanshaw**, '53, since 1975 research hydrologist in the office of the Northeastern Regional Hydrologist, was designated acting assistant for research to fill the vacancy resulting from Wesson's promotion.

. . . **Mihran N. Nalbandian**, '63, reports that he is now geologist/regional planner with the U.S. Department of Reclamation Planning and Standards, Office of Surface Mining Reclamation and Enforcement. . . . **Cyril J. Galvin**, Ph.D.'63, formerly chief, Coastal Processes Branch, U.S. Army Coastal Engineering Research Center, Washington, D.C., is now a licensed consulting coastal engineer in Springfield, Va. During May 18-20, he was coordinator for a short course in "Coastal Engineering Design" held in Alexandria, Va., and in mid-October he served as coordinator for a short course in "Shorelines, Waterways, and Harbors," held in Arlington.

Farouk El-Baz (former graduate student) recently left his position as director—earth and planetary sciences at the Air and Space Museum

of the Smithsonian Institution, Washington, D.C., to become vice-president of international development at the Itak Corp., Lexington, Mass. He was profiled in *Science* magazine recently (September 28, 1978).

Walter E. Seibert, Jr., '49, registered professional geologist, recently announced the formation of Seibert Mineral Service, Teaneck, N.J., to provide guidance to the mineral industry. . . . **Virginia F. Ross**, Ph.D.'53, was one of the leaders of a China exchange delegation trip for herbs and agriculture in October. The tour, designed to provide participants an opportunity to learn about Chinese herbs and agriculture and their relation to health and culture, was sponsored by the U.S.-China Peoples Friendship Association—Eastern Region. . . . **Razel Wittels (Kallberg)**, '69, married to Keith Kallberg (Course I, S.M.'68) with his own engineering consulting business in civil/structural engineering in South Berwick, Maine, writes that in addition to taking care of their two children, aged 9 and 7, she is teaching physics and physical science at Berwick Academy.

Enders A. Robinson, Ph.D.'54, continues his impressive productivity as an author of works on data processing. So far he has published 16 books, 8 with co-authors and 8 alone, the most recent being *Migration of Geophysical Data* (International Human Resources Development Corp., Boston, 208 pp., 1983). In addition to his consulting work and writing, carried on from his home in Lincoln, Mass., he is currently serving as distinguished professor of geophysics at the University of Tulsa. . . . **Mead L. Jensen**, Ph.D.'51, recently revised his widely used *Economic Mineral Deposits* (John Wiley & Sons, New York, 3rd edition). Word came at Christmas time from Cape Town, South Africa, that **Louis H. Ahrens**, formerly on the Course XII faculty (1948-1953), would be publishing a new book on *Ionization Potentials* (Pergamon Press) in mid-1983 and would be retiring from teaching in 1984.

Paul T. Walton, Ph.D.'42, writes that he has 12 horses at his polo club, using six for each game—one for each chukker—and keeping the other six for his girl groom who also plays. When not playing polo, he keeps a close watch, from his office in Salt Lake City, Utah, on the drilling of oil prospects in which he has an interest. . . . **Wallace W. Wrigley** (former undergraduate 1964-65) is now with Occidental Exploration and Production Co. as Alaska district geologist. He and his family make their home in Bakersfield, Calif.—Robert R. Shrock, Professor Emeritus, M.I.T., Room 54-926, Cambridge, MA 02139

XIII

Ocean Engineering

D.F. Kinert, S.M.'42, reports that he attended the 50th reunion and homecoming of the U.S. Naval Academy on October 22-24, 1982. . . . **Robert K. Johnson**, S.M.'67, is currently a naval architect in Largo, Fla., doing sailing yacht designs for vari-

ous yacht builders and owns his own company building traditional cruising sailing yachts in molded fiberglass. . . . **Donald Distant**, S.M.'80, has been appointed chief engineer (electrical and marine) with the Port of Singapore Authority in May 1982, responsible for all electrical engineering and marine engineering activities in P.S.A.

Theotokis S. Milas, S.M.'71, is presently superintendent engineering with Cove Shipping, New York City. . . . **Robert J. Bosnak**, '60, chief, Mechanical Engineering Branch, Division of Engineering of the U.S. Nuclear Regulatory Commission, was a recipient of the 1982 American Society of Mechanical Engineers' Bernard F. Langer Nuclear Codes and Standards Award. The award was for "outstanding professional and technical contributions in the development of ASME nuclear codes, standards, and accreditation programs." . . . **Robert I. Price**, '53, recently retired as the third ranking officer of the U.S. Coast Guard, commanding both the New York District and the Atlantic area, has received the annual Vice Admiral "Jerry" Lane Medal for "outstanding accomplishment in the marine field," by the Society of Naval Architects and Marine Engineers. His naval career has focused on the improvement of national and international standards for maritime safety and environmental protection.

XIV

Economics

Arthur G. Ashbrook, Jr., Ph.D.'47, reports that he has retired from the Central Intelligence Agency after 28 years of service as an economist. For four years he was assigned to the faculty at the National War College, Washington, D.C., and intends to continue teaching and research in the "dismal science." . . . Two graduates of the department have been re-elected to Congress: **Howard E. Wolfe**, Ph.D.'62, won his third consecutive term in Congress from Michigan's third Congressional district, the area encompassing Kalamazoo; and **Les Aspin**, Ph.D.'66, won his third consecutive term in Congress from Wisconsin's first district.

XV

Management

Project management will be so different by 1990 that "a new breed of manager will be needed to cope with changes," says **Albert J. Kelley**, '48, president of the Arthur D. Little Program System Management Co. The changes: increasing constraints by such external factors as environmental and government regulation, multiple financial arrangements, new risk due to advanced, unproved technology, and inflationary pressures. These issues and others are the subject of *New Dimensions of Project Management* (Lexington Books, 1983), a book of 15 essays by Dr. Kelley and other project management specialists including **John R. White**, S.M.'63, senior vice-president—strategic planning at Arthur D. Little, Inc.; Professor **Mel Horwich** of the Sloan School of Management; **John F. Magee**, president of Arthur D. Little, Inc.; and **Robert C. Seamans, Jr.**, Sc.D.'51, Henry R. Luce Professor of Environment and Public Policy at M.I.T.

Richard A. Michaelson, S.M.'77, reports, "I have recently been made vice-president at MetPath, Inc., responsible for billing and receivables. MetPath, a wholly-owned subsidiary of Corning Glass, is in the clinical laboratory business. . . . **Warren H. Hausman**, Ph.D.'66, has been appointed chairman of the Industrial Engineering and Engineering Management Department at Stanford University, Palo Alto, Calif. His area of expertise is in production/operations management and analysis. . . . **George E. Williams**, S.M.'49, corporate vice-president of United Technologies Corp., has taken an early retirement

and has joined Kensington Management Consultants, Stamford, Conn., as a senior vice-president.

Charles C. Holcomb, S.M.'75, is currently the commanding officer of USS *Canopus* and resides in Charleston, S.C. . . . **Aristea Xafa**, S.M.'75, has left her London-based position as vice-president—finance of Saudi REDEC and is now in charge of Boston-based Global Investments Limited. She writes that she would like to hear from alumni in microelectronics and computer manufacturing concerns and those engaged in R&D equity financing. . . . **W. John Swartz**, S.M.'67, has been appointed executive vice-president of Santa Fe Industries, Inc., Chicago, Ill. . . . **William O. Schach**, S.M.'50, is currently senior vice-president of Merrill Lynch, Pierce, Fenner, and Smith, Inc.

Frederic C. Westendorf, S.M.'64, is currently business planning manager for IBM Europe/ Middle East/Africa, White Plains, N.Y. . . . **Debra Greenberg**, S.M.'78, reports that she has founded her own consulting firm in New York City.

Otto H. Poensgen, Ph.D.'64, who was assistant professor at M.I.T.'s Sloan School (upon his graduation until 1967) and later was appointed to a chaired professorship in industrial management at the University of Saarland, Saarbrücken, Germany, passed away on October 29, 1982. He was well known in the U.S. and abroad for his research and teaching in management science, business strategy, and organizational structure. During a sabbatical leave in 1980, he continued his research at M.I.T. . . . **Donald G. Robbins, Jr.**, of Fairfield, Conn., passed away on October 11, 1982; no details are available.

Sloan Fellows

Ormand J. Wade, S.M.'73, president and chief operating officer of Illinois Bell Telephone Co., has been elected to the boards of Harris Bankcorp, Inc., and Harris Trust and Savings Bank. . . . **Leroy E. Day**, S.M.'60, writes, "I retired from NASA and the Space Shuttle Program to start my own consulting business for aerospace and management—business expanding. I was also awarded NASA's Distinguished Service Medal for work on the space shuttle." . . . **Brian J. Kelly**, S.M.'73, vice-president of marketing of Bell of Pennsylvania and Diamond Star Telephone Co., has been elected to the Board of Trustees of Hahnemann University, Philadelphia, Penn.

John C. Davis, S.M.'56, senior vice-president and a director of Santa Fe Railway, Chicago, retired from the firm in December 1982. . . . **Eric W.A. Lange**, S.M.'62, has joined the staff of Failure Analysis Associates, Troy, Mich. . . . **Sam R. Willcox**, S.M.'65, formerly vice-president of American Telephone & Telegraph Co., New York City, has become the firm's executive vice-president of marketing (interexchange organization). . . . **William H. Springer**, S.M.'68, executive vice-president of finance for Illinois Bell Telephone Co., has become its senior vice-president and secretary.

Steven J. Miller, S.M.'79, writes, "I was recently married to Janet Patricia Beal on September 11, 1982, and am currently director of marketing—western region for Data Resources, Inc., a leader in economic forecasting and consulting." . . . **William S. Wheeler, Jr.**, S.M.'54, reports, "I took early retirement as a senior vice-president of Englehard Industries earlier this year and with an associate bought a small manufacturing company which manufactures bulk material handling equipment. The company is Buck El, Inc. Thoroughly enjoying the independence of being the C.E.O. of my own company." . . . **Cline W. Frasier**, S.M.'72, a senior technical member of the Manufacturing Automation and Computation Department at the Charles Stark Draper Laboratory, Cambridge, has been appointed head of the department.

Robert E. Workman, S.M.'58, a retiree after 39 years of service at Goodyear Tire and Rubber Co., Akron, Ohio (his latest position was vice-

president of general products development), passed away on November 18, 1982. He was a past president of the International Institute of Synthetic Rubber Producers, a member of the American Chemical Society and of the American Institute of Chemical Engineers.

Management and Technology Program

Geoffrey N. Andrews, S.M.'82, is currently with the New Opportunities Department at Pilkington Brothers in England, where he recently headed a corporate-wide project called Quest—ferrating out underutilized skills and technology within the firm. He saw Professor **Edward B. Roberts**, Ph.D.'57, briefly during Ed's trip to Pilkington at the end of November.

XVI

Aeronautics and Astronautics

The spread of nuclear power to developing nations is dangerous because it lowers their threshold for nuclear weapons development, says **John P. Holdren**, '65, professor of energy and resources at the University of California at Berkeley. A nuclear power program assures the presence of the technical skills needed to operate a weapons program and often includes facilities for converting reactor fuel into weapons-usable material, Dr. Holdren wrote early this year in the *Bulletin of the Atomic Scientists*. A power program also reduces the marginal cost of a weapons program, and it lowers some of the political barriers to nuclear weapons commitments, Dr. Holdren said.

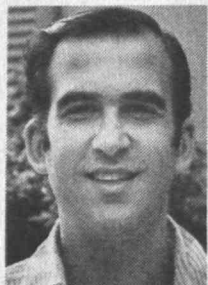
Roger Neeland, S.M.'70, writes, "After teaching at the U.S. Air Force Academy for several years in the Department of Astronautics, and two years heading FAA's Airborne Systems Branch in their Systems Research and Development Service, I am now responsible for analysis to support the Air Force Systems Command long-range planning." . . . **Louis H. Benzing**, S.M.'52, executive vice-president of Jofee Marketing International, has taken on the additional position of president and chief executive officer at the Micro Z Corp., Monrovia, Calif. . . . **Tore Christiansen**, S.M.'82, has recently taken up an engineering position in Det Norske Veritas, an international Norwegian classification society for ships and off-shore structures, and is presently working in Oslo, Norway.

Henry F. Lloyd, S.M.'46, reports that he is still a college administrator at Flagler College and has been in this position since retirement from the U.S. Navy. . . . **Robert Schegerin**, S.M.'74, is presently employed at Talasa Law and Technologies, Woodbury, Conn. . . . **Jack E. Steiner**, S.M.'41, vice-president of corporate product development at the Boeing Co., recently served as a witness on hearings on government policy toward aeronautical research chaired by Congressman Dan Glickman, chairman of the Subcommittee on Transportation, Aviation and Materials.

Technology and Policy Program

Julian Villalba, S.M.'80, has recently completed his doctorate at M.I.T. in international technology transfer. He will teach at the Instituto de Estudios Superiores y Administracion, Caracas, and also plans to do consulting work on state-owned enterprises and public administration. . . . **David Rubin**, S.M.'81 is working for the city of San Francisco as a member of a task force studying district heating systems.—Richard de Neufville, Chairman, Technology and Policy Program, M.I.T., Room 1-138, Cambridge, MA 02139.

Sneaky vs. Freddy



Allan J. Gottlieb, '67, is associate research professor at the Courant Institute of Mathematical Sciences of New York University; he studied mathematics at M.I.T. and Brandeis. Send problems, solutions, and comments to him at the Courant Institute, New York University, 251 Mercer St., New York, N.Y., 10012.

Since I've not reviewed the ground rules of "Puzzle Corner" for more than a year, let me do so now for the benefit of new readers.

In each issue we present five regular problems (the first of which is chess- or bridge-related) and two "speed" problems. Readers are invited to submit solutions to the regular problems, and one submitted solution for each problem is selected for publication three issues later. We also list other readers whose solutions were successful. For example, solutions to the problems you see below will appear in the August/September issue. Since I must submit that column sometime in May (today is January 15), you should send your solutions to me during the next few weeks. Late solutions, as well as comments on published solutions, are acknowledged in subsequent issues in the section entitled "Better Late than Never." For example, comments appear in this issue on previously published solutions to two problems, **JUL 1** and **Y1982**.

For "speed" problems the procedure is quite different. Often whimsical, these problems should not be taken too seriously. If the proposer submits a solution with the problem, that solution appears at the end of the same column in which the problem is published. For example, solutions to the "speed" problems printed in this issue are given at the end of this column. Only rarely are comments on "speed" problems published or acknowledged.

There is also an annual problem, published in the first issue of each new year; and sometimes we go back into history to republish problems which remained unsolved after their first appearance.

All problems come from readers, and

all readers are invited to submit favorites. I'll report on the size of the backlog, and on criteria used in selecting problems for publication, in future issues.

Problems

APR 1 Here is a zany problem from Arthur Polansky, who recounts a conversation with a friend:

"I know you've played duplicate bridge with life masters and once received an invitation to the Brisbane regionals. But have you ever played mixed-pairs quadruplicate?" my friend asked. Reluctantly I confessed that I had not. My friend explained: "Each team of four players is split amongst four tables so that one member plays North, one South, one East, and one West. Each deal of the cards is played four times, once at each table."

"But that means that I always get a partner from an opposing team," I complained.

"Precisely," my friend said. "Cuts down on preplanned conventions, like the 17-19-point left-eye-scratch. Also does wonders for the scoring." I could imagine. "Consider deal 23 from last night. Team 5, the Four Spades, reached four spades at all four tables."

By now I was mildly disgusted. "With such bidding prowess, why do you allow these turkeys to keep playing?"

"They own the club," was my friend's answer.

Hastily bidding adieu (which was immediately doubled for takeout), I raced home. Then I realized that the self-styled tournament director had failed to show me the deal in question. Can you? (That is, find a deal such that four spades, when played from any position, will be set at least seven tricks (i.e., the defense will make four spades). Naturally, the set will be perforce: the declarer will do everything in his power to prevent being set and to minimize the damages if being set becomes inevitable.)

APR 2 Frank Rubin wants a defect-free plane of words:

Shown below is a simple word square.

A	C	E
P	A	R
E	R	A

We could fill the plane with such word squares so that every cell of an infinite grid lay at the intersection of two words. However, such an arrangement would have two defects: (1) the pattern would

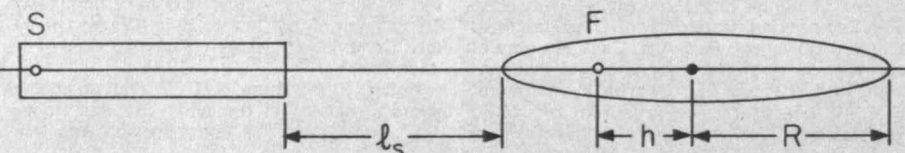
be repetitive, and (2) the words would not all be interconnected. Show how these defects can be fixed; i.e., fill the plane with an infinite number of words so that the pattern does not repeat in any row or column, every cell lies at the intersection of two words, and every word is connected to every other one by a chain of intersecting words. Do not use any two-letter words.

APR 3 Here's one from Ming Chung, who first published it (and the diagram at the bottom of this page) in the student newsletter of the M.I.T. Physics Department:

One afternoon in a swamp Sneaky the snake, whose mass is M_s and length ℓ_s , was resting on the left end of a log of length L and mass M_l when he suddenly remembered that he was hungry. After a few moments of looking around, he found Freddy the frog sitting on a large disk-shaped leaf of radius R and mass M_o h cm. away from the center of the disk. Initially the disk was $4/5 \ell_s$ cm. away from the right end of the log. Quite naturally Sneaky started moving toward Freddy, and Freddy, who was ignorant of the laws of physics, started jumping for his life. However, when Freddy remembered that Sneaky had his best friend for breakfast in the morning he was overcome by the rage and desire for revenge, and he turned around to charge against Sneaky. Well, normally it would have been a dumb move. But the laws of physics reward the courageous; when Freddy stopped at a point on the disk and realized that his attempt was futile if not suicidal, the disk was just out of the reach of Sneaky, who was on the right end of the log by that time. Sneaky could not swim, so the good guy was saved and the bad guy had a hungry afternoon. It's a dumb story, you say. Well, if you'd like to entertain your intelligence, consider the following question: Can you locate the point where Freddy stopped? Assume all motions occurred on a line, and the water offered no resistance. Both the log and disk have a uniform mass density.

APR 4 Ronald Burde doesn't seem to know enough to come in out of the rain. Instead he asks:

Assuming the sudden onset of steady rainfall, will a person remain dryer by walking or running any given distance to shelter? (Mr. Burde remarks that this problem has reached the level of a friendly "cause celebre" among some



fellow-alumni. He agrees with them that the solution to the problem is straightforward and that it has been solved many times, but agreement is lacking on the answer.)

APR 5 Peter Groot wants you to find positive integers a , b , and c such that $a^3 + b^4 = c^5$.

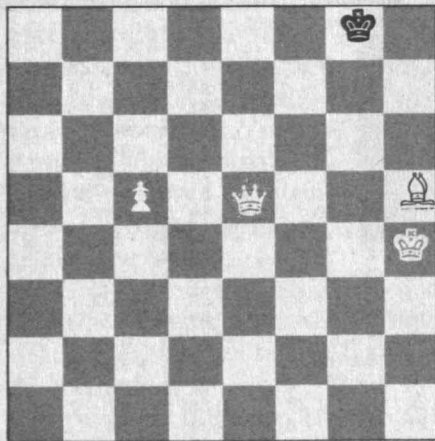
Speed Department

APR SD1 Rufus Briggs will let you have additional information, but not much: Given a glass tube 6 inches in diameter and 60 inches long. The tube is capped and sealed at one end and mounted vertically. The bottom 30 inches of the tube is filled with thick molasses and the top 30 inches with a medium grade of oil. A 1-inch polished steel ball is allowed to fall through the liquids, and it takes $t_0 = 2.73$ seconds to fall half way down the tube. What is the time t_f for the ball to fall the entire length of the tube? To answer this question you may have one and only one additional piece of information. Identify the information you have chosen, and write the equation for solving the problem.

APR SD2 David Evans wonders what common five-letter word is spelled wrong by nearly every M.I.T. graduate.

Solutions

N/D 1 White to mate in three moves:

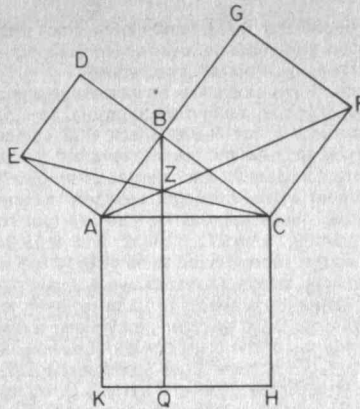


The following solutions are from Darryl Hartman:

Q-B3 K-B1
Q-KN3 K-K2
Q-Q6
or
B-B7 K-R2
Q-R8 K-R3

Also solved by Matthew Fountain, George Farnell, Ronald Raines, Robert Holt, Richard Hess, Randy Kimble, Winslow Hartford, and the proposer, Bob Kimble.

N/D 2 Given ABC is a right triangle; B is a right angle; ABDE, BCFG, and ACHK are the squares on the sides; and BQ is parallel to AK. Determine if the three lines EC, BQ, and AF meet at a point Z as they appear to in the drawing.

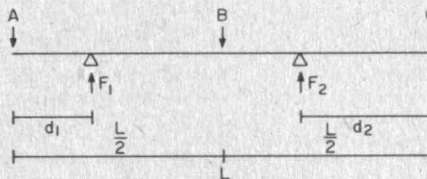


Avi Ornstein found that analytic geometry makes this problem rather easy: Let AC and BQ be the x and y coordinates, respectively. In addition, let A be $(-a, 0)$, let B be $(0, b)$, and let C be $(c, 0)$. Then E is $(-a - b, a)$, F is $(b + c, c)$, and Q is $(0, -a - c)$. The slope of AF is $c/(a + b + c)$ and its y -intercept is $ac/(a + b + c)$. The slope of EC is $-a/(a + b + c)$ and its y -intercept is $ac/(a + b + c)$. AF and EC therefore meet on line BQ at point Z.

Also solved by Winslow Hartford, Richard Hess, Gabrielle and J. Donnay, Paul Sonn, Phelps Meaker, Mary Lindenberg, Steve Feldman, Eugene Boehne, John Woolston, Dave Simen, Harry Zarembo, Emmet Duffy, Matthew Fountain, Robert Holt, and Farrel Powsner.

N/D 3 A massless beam of length L is supported by two stanchions at distances d_1 and d_2 from the ends. The beam is loaded with point masses A, B, and C at the ends and midpoint. What is the downward force on each stanchion?

Robert Holt sent us a fine solution:



To simplify the notation, say that the point masses have weights A, B, and C. (If A is the mass, then the weight is Ag , and A, B, and C must be replaced by Ag , Bg , and Cg , respectively, in what follows.) There are five forces acting on the beam; three are the weights A, B, and C, and the other two are the upward forces due to the stanchions. Call these forces F_1 and F_2 . Apparently the beam is supposed to be at rest, so the torque about each stanchion is zero. The magnitude of the torque about the left stanchion is $Ad_1 - B[(L/2) - d_1] - C(L - d_1) + F_2(L - d_1 - d_2)$. Setting this equal to 0 yields

$$Ad_1 - B[L/2] + Bd_1 - CL + Cd_1 + F_2(L - d_1 - d_2) = 0$$

$$(A + B + C)d_1 - [(B/2) + C]L + F_2(L - d_1 - d_2) = 0$$

$F_2 = [(1/2)B + C]L - (A + B + C)d_1 / (L - d_1 - d_2)$. Similarly, the magnitude of the torque about the right stanchion is

$$A(L - d_2) + B[(L/2) - d_2] - Cd_2 - F_1(L - d_1 - d_2) = 0$$

and this gives

$$F_1 = [(1/2)B + A]L - (A + B + C)d_2 / (L - d_1 - d_2)$$

Of course, by Newton's Third Law of Motion the downward force on the left stanchion is $[(1/2)B + A]L - (A + B + C)d_2 / (L - d_1 - d_2)$, and the downward force on the right stanchion is $[(1/2)B + C]L - (A + B + C)d_1 / (L - d_1 - d_2)$.

Also solved by Richard Hess, John Boynton, Irving Hopkins, Howard Wagner, John Prussing, Haus Meier, George Piotrowski, James Reswick, John Woolston, Matthew Fountain, Robert Slater, and Harry Zarembo.

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N/D 4 Will the three hands of a clock (hours, minutes, and seconds) ever divide the clock face into three equal parts? If so, when?

James Reswick sent us an interesting analogy: I'm not much on mathematical proofs, so I tried a model clock in my Radio Shack PC2 computer. The program runs the "clock" very fast but slows down to calculate for each degree of second-hand movement when the angle between the minute and hour hands approaches 120°. At four times, viz: 2:54:32, 5:05:27, 6:54:32 and 9:05:27, it showed the second hand to be only 10° off when the minute and hour hands were exactly 120° apart. Thus there seems to be no solution to the problem but there are four pretty close answers. Reminds me of the old story about a mathematician and an engineer. Each stood at one end of a long room. At the other end stood a lovely young lady. They were told to approach her by walking half the distance, to stop, then to walk half the remaining distance, stop, and to continue until they reached the maid to receive a rewarding kiss. The mathematician declared "But according to Zeno I'll never reach her," and he left the room in disgust. The engineer started walking with alacrity saying, "I learned about Zeno also—but I'll get close enough!"

J. Meier sent us a more conventional treatment: The second hand advances 360° per minute; the minute hand advances 6° per minute; and the hour hand advances 0.5° per minute. The minute hand gains 5.5° per minute [= (11/2)° per minute] on the hour hand. The second hand gains 354° per minute on the minute hand. The first condition is that the minute hand be 120° or 240° ahead of the hour hand. Starting at X:00:00 (where the minute and second hands are at 0° and the hour hand is at X hours, or 30X°), it takes (30X + 120) / 2/11 and (30X + 240) / 2/11, or (60X + 240) / 11 and (60X + 480) / 11 minutes, respectively, to meet the first condition. This repeats every 12 hours, i.e., X = 0, 1, ..., 11. The corresponding number of degrees moved by the minute hand are (360 + 1440) / 11 = 360(X + 4) / 11 and 360(X + 8) / 11, respectively. As a check consider X = 7 and X = 3, respectively. The minute hand moves 360° after 7:00:00 and after 3:00:00 to come to 8:00:00 and 4:00:00, respectively, where it is 120° and 240°, respectively, ahead of the hour hand. The second condition is that the second hand be 120° or 240° ahead of the minute hand. Starting at X:Y:00, where the second hand is at 0° and the minute hand at Y minutes, or 6Y° (X does not matter), it takes (6Y + 120) / 354 or (6Y + 240) / 354 minutes, respectively, to meet the second condition. This repeats every hour, i.e., Y = 0, 1, ..., 59. The corresponding number of degrees moved by the minute hand are (6Y + 120) / 59 and (6Y + 240) / 59, respectively. As a check consider Y = 39 and Y = 19. In both cases it takes exactly one minute to fulfill the second condition at 40 minutes and 20 minutes, respectively, after the full hour. For both conditions to be fulfilled simultaneously, 360(X + 4) / 11 or 360(X + 8) / 11 must have a fraction in excess over a full integer equal to the fraction over a full integer of (6Y + 120) / 59 or (6Y + 240) / 59, respectively. But this is not possible for the stated values of X and Y.

Also solved by Harry Zarembo, Richard Hess, Robert Holt, Winslow Hartford, C. L. Baker, Emmet Duffy, Matthew Fountain, John Woolston, Dave Simen, Norman Wickstrand, Ken Haruta, and the proposer, Alan Davis.

N/D 5 Six different numbers are selected arbitrarily from eight positive consecutive integers. The resulting selection includes the smallest and largest of the eight numbers and can be separated into three pairs of numbers, each of which contains consecutive numbers. The sum of the six integers is three times a number N, and the sum of their cubes equals the cube of N. Find N and each of the integers selected.

The following solution is from John Bucsele: The eight consecutive integers may be written as n, n + 1, ..., n + 7 for some integer n ≥ 1. There are three ways to select six of these integers so

that the smallest and largest are included and so that they may be divided into three pairs of consecutive numbers. They are

n, n + 1, n + 2, n + 3, n + 4, n + 5, n + 6, n + 7
n, n + 1, n + 3, n + 4, n + 6, n + 7
n, n + 1, n + 4, n + 5, n + 6, n + 7
In the first case, the sum of the six numbers is 6n + 19. This is not divisible by 3, hence cannot equal 3N. Likewise, in the third case, the sum of the six numbers is 6n + 23, also not divisible by 3. Thus only the second case can occur. Then, the sum is 6n + 21, so we conclude that 3N = 6n + 21, or N = 2n + 7. Next, n³ + (n + 1)³ + (n + 3)³ + (n + 4)³ + (n + 6)³ + (n + 7)³ = 6n³ + 63n² + 333n + 651. Setting this equal to N³ = (2n + 7)³ = 8n³ + 84n² + 294n + 343, we obtain 2n³ + 21n² - 39n - 308 = 0. It is easy to see that the only possible positive integral solution of this equation is 4. Thus N = 15 and the six selected integers are 4, 5, 7, 8, 10, and 11.

Also solved by Richard Hess, Robert Slater, Robert Holt, Howard Wagner, Steve Feldman, Roger Milkman, Samuel Levitin, Howard Sard, Richard Bernicker, Emmet Duffy, Matthew Fountain, David Simen, Frank Carbin, John Woolston, Ronald Raines, Norman Wickstrand, and the proposer, Harry Zarembo.

Better Late Than Never

JUL 1 The answer supplied by the proposer was correct, but I carelessly misread it.

A/S 4 Richard Hess has responded.

OCT 1 Richard Hess has responded.

OCT 3 Richard Hess has responded.

OCT 5 Richard Hess, Michael Jung, and Avi Ornstein have responded.

Y1982 John Fine, Erik Anderson, Thomas Weiss, Phelps Meaker, and Harry Hazard noticed that the published solution was not optimal. A revised solution follows. To clarify the problem let me add that we seek a minimum number of operations (each addition, subtraction, multiplication, division, and exponentiation counts as one operation); and among answers having equal numbers of operations, we prefer those with 1, 9, 8, and 2 used in order.

1	1 ⁹⁸²	36	18 + 9 × 2
2	1 ⁹⁸ × 2	37	1 × 9 × 28
3	1 ⁹⁸ + 2	45	18 × 2 + 9
4	18/9 × 2	47	19 + 28
5	9 - 12 + 8	49	1 × 98/2
6	9/12 × 8	50	1 + 98/2
7	18 - 9 - 2	54	(19 + 8) × 2
8	1 ⁹² × 8	57	1 + (9 - 2) × 8
9	91 - 82	64	1 ⁹ × 8 ²
10	1 ⁸² + 9	70	81 - 9 - 2
12	12 ^(9 - 8)	74	92 - 18
13	19 - 8 + 2	75	91 - 8 × 2
14	1 + 9 + 8/2	81	18 × 9/2
15	19 - 8/2	82	1 ⁹ × 82
16	1 ⁹ × 8 × 2	84	1 × 92 - 8
18	18/2 + 9	85	1 + 92 - 8
19	1 × 28 - 9	87	1 × 89 - 2
20	1 - 9 + 28	88	1 + 89 - 2
21	1 × 29 - 8	89	1 ² × 89
22	(19 - 8) × 2	90	1 ² + 89
25	19 + 8 - 2	91	1 × 9 + 82
27	18 × 2 - 9	92	1 + 9 + 82
28	1 ⁹ × 28	95	91 + 8/2
30	19 × 2 - 8	98	1 ² × 98
33	(1 + 2) × 8 + 9	100	1 × 98 + 2
35	19 + 8 × 2		

Proposers' Solutions to Speed Problems

SD 1 There is one elegant and simple answer to the problem that is quickly seen by those observant people who do not overlook the obvious: 1. They ask for the time t_M required by the ball to fall through the molasses; and 2. They write the equation (called for in the problem). The total time $t_T = t_M + 2.73$.

SD 2 Wrong.

The United States can incur other long-term political liabilities by intermingling military and civilian activities in space missions. For example, using the shuttle for experiments with laser or particle-beam weapons might be viewed as contrary to the spirit, if not the letter, of international agreements. Similarly, the emplacement of civilian navigation satellites accurate enough to launch first-strike missiles from the sea would raise serious problems. In fact, including any defense experiments on an otherwise unclassified mission might raise exaggerated suspicions about the type and amount of military work being done under the guise of "peaceful" space activity. Even American scientists are likely to have qualms about "piggybacking" their experiments on

space missions that are widely suspected, justifiably or not, of having a primarily military purpose. There is considerable political advantage in being uncompromisingly open.

Moreover, both the United States and the Soviet Union have a basic interest in avoiding extension of the potential battlefield to space. In the long run, we have more to gain than to lose by avoiding the militarization of space. Because experience suggests that new capabilities gained by one side will be quickly matched by the other, any new weapons are likely to be soon available to both sides. Each ends up less secure than if neither had acquired the weapons in the first place. The only exception appears to be in intelligence-gathering capabilities, which are more valuable to the United States because of the secretiveness of the Soviet Union.



The separation of civilian and military space activities has served the country well and should be maintained.

Competition and Cooperation in Space: Each in Its Place

Of all the features of the space program embodied in the 1958 act, its international orientation was probably the least questioned. For one thing, the American lead in space technology among Western nations seemed unassailable. For another, the United States needed political measures to deemphasize its reputation of being primarily interested in military power. Since the goals of the new U.S. space program were avowedly political rather than military, stressing its international, cooperative aspects was especially sensible. This was also consistent with other American foreign policy programs at the time: the Marshall Plan, the Atoms-for-Peace initia-

tive, and the Eisenhower "open skies" proposal. In each, the United States offered to share its technological capabilities with others under minimal political preconditions. This approach was more consistent with the concept of "leadership" embodied in the Space Act than the "hegemony" advocated by those who favored a space program run by the military.

There is little question that American willingness to make its space technology available to other nations has been of great political benefit. Not all observers would agree on the economic benefits of this policy, but cooperation in space has generally been a positive-sum game in which all have profited. And as long as the United States is willing to invest enough to maintain at least a modest technological lead over potential competitors in space services, sharing probably remains advantageous, both politically and economically. Only if potential competitors are planning

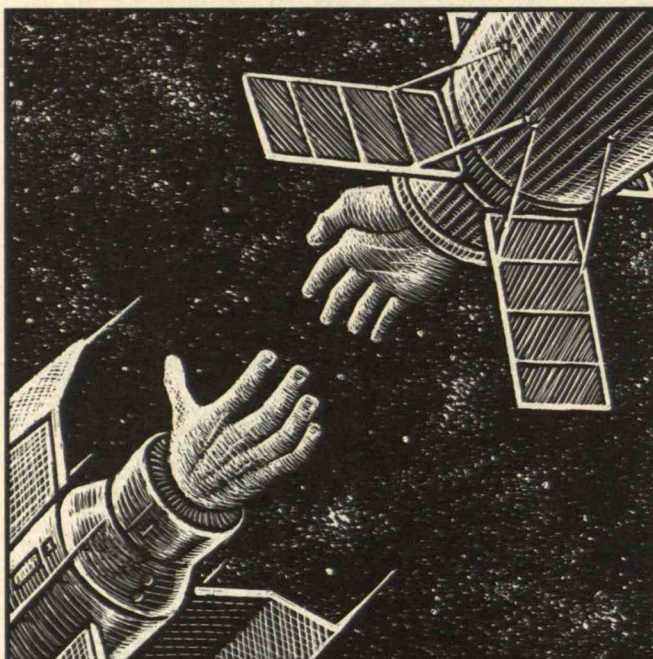
to consistently outspend us in space technology should we reconsider.

But even in a competitive environment—which would benefit all users of space services by stimulating innovation—cooperation still makes sense in some cases. For example, substantial savings can accrue when many nations form a partnership to build and use a single facility, as in the case of Intelsat, the international consortium for satellite communications. Where such economies are possible, international competition can lead to wasteful duplication, a problem that may now be starting in the communications-satellite field. Another reason for cooperating is that space can become saturated, as in the case of the limited frequency slots available to satellites in geostationary orbit.

Where such “parking orbits” are in short supply, competition can lead to political conflict, especially between spacefaring and developing nations. On the other hand, the shortage of parking orbits may be alleviated by further advances in technology. The United States has maintained this position in international forums, but it has not backed its arguments with the necessary investments.

In the long run, as space operations move from R&D into routine services, they should be placed in an international framework. The form that appears to offer the greatest flexibility is a multinational corporation such as Intelsat, even if it has to receive subsidies from participating governments.

However, there are growing political pressures against this approach. For example, many countries are beginning to build their own communications satellites despite membership in Intelsat. To do so,



Cooperation
in space has generally been
a positive-sum game
from which all have
profited.

these countries must convince Intelsat's board that a national system will not restrict the corporation's revenues. Although this may be difficult, political pressures may oblige the board to interpret that requirement liberally.

For example, France is now planning to put up its own remote sensing satellite, SPOT, in some ways more advanced than the U.S. Landsat D. France will offer the satellite's services to all comers, with more flexible institutional arrangements and dependable service than seems likely with Landsat. Similarly, the European Space Agency will offer an expendable launcher, Ariane, as an alternative to the shuttle. It already has several American takers, although the recent failed launch of an Ariane rocket may change

people's attitudes. At this stage, competition in space services may be healthy and even ease rigidity and improve the reliability of the U.S. government. On the other hand, such heavily subsidized “national-champion” programs could lead to wasteful competition.

Competition in civilian space activities, where desirable, might more profitably occur among multinational entities rather than nations. A possible model is the aircraft industry, in which both development and production are increasingly multinational, with joint ventures and coproduction. Thus, the latest generation of aircraft includes components and technologies from many different countries. This is happening because the resources, both technical and financial, required to develop and deploy a modern commercial aircraft are beginning to tax even the largest corporate budgets.

This is even truer of space ventures and will become increasingly so as they grow in scope and the relative size of the U.S. economy shrinks. Although a multinational structure would be most attractive for privately financed commercial space applications (where expenses may be recovered from users), it could apply to publicly financed scientific undertakings as well. The cooperation between the United States and Europe (mainly Germany) on the Spacelab package for the shuttle is already a precedent. And after more than a decade of false starts, a group of European countries have finally achieved some cooperation through the European Space Agency.

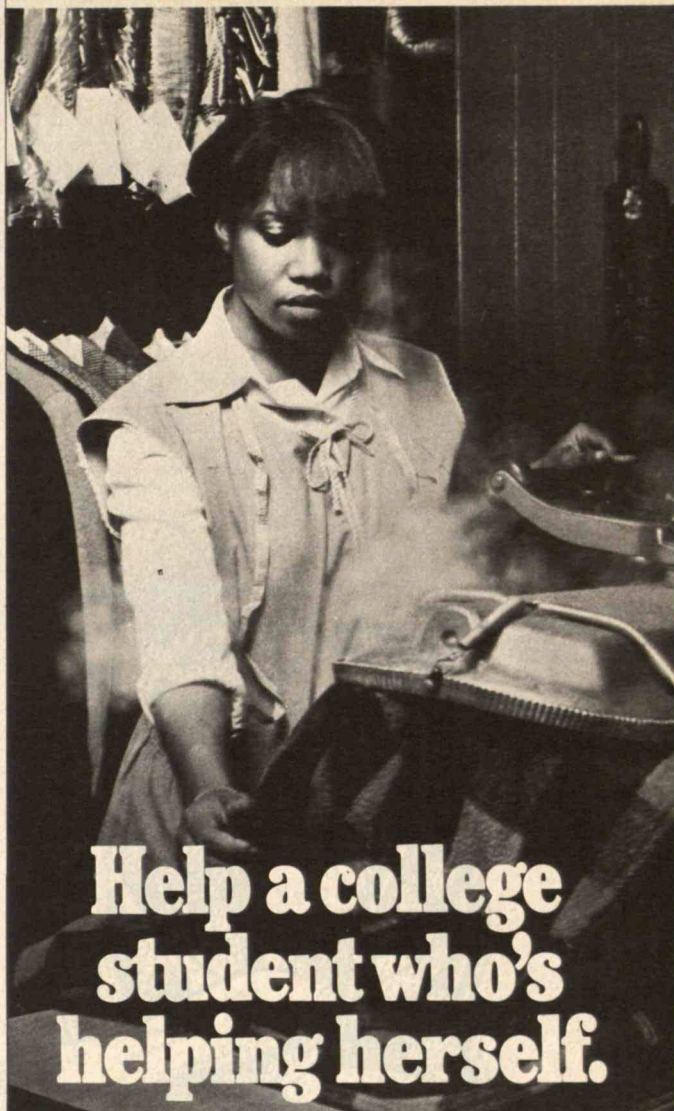
Space is inherently amenable to "global technology." The essential activity takes place in a "commons" outside the sovereignty of any single nation and requires a high degree of cooperation among installations all over the world—from tracking stations to ground terminals to international data-management centers. Thus, space would appear to be an ideal candidate for multinational corporations. Such cooperation is more difficult to manage than national activities, and in some cases may not be worth it. On the other hand, international agreements are much more difficult to renege on than national budgetary commitments. And the complexity of multinational operations may be largely offset by the greater international stability that results.

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This article is adapted from "Motivations and History of the Space Program," presented at the International Symposium on the History and Future of Space Activities in Washington, D.C., on October 14, 1982. The symposium was sponsored by the National Air and Space Museum of the Smithsonian Institution and the National Academy of Sciences.



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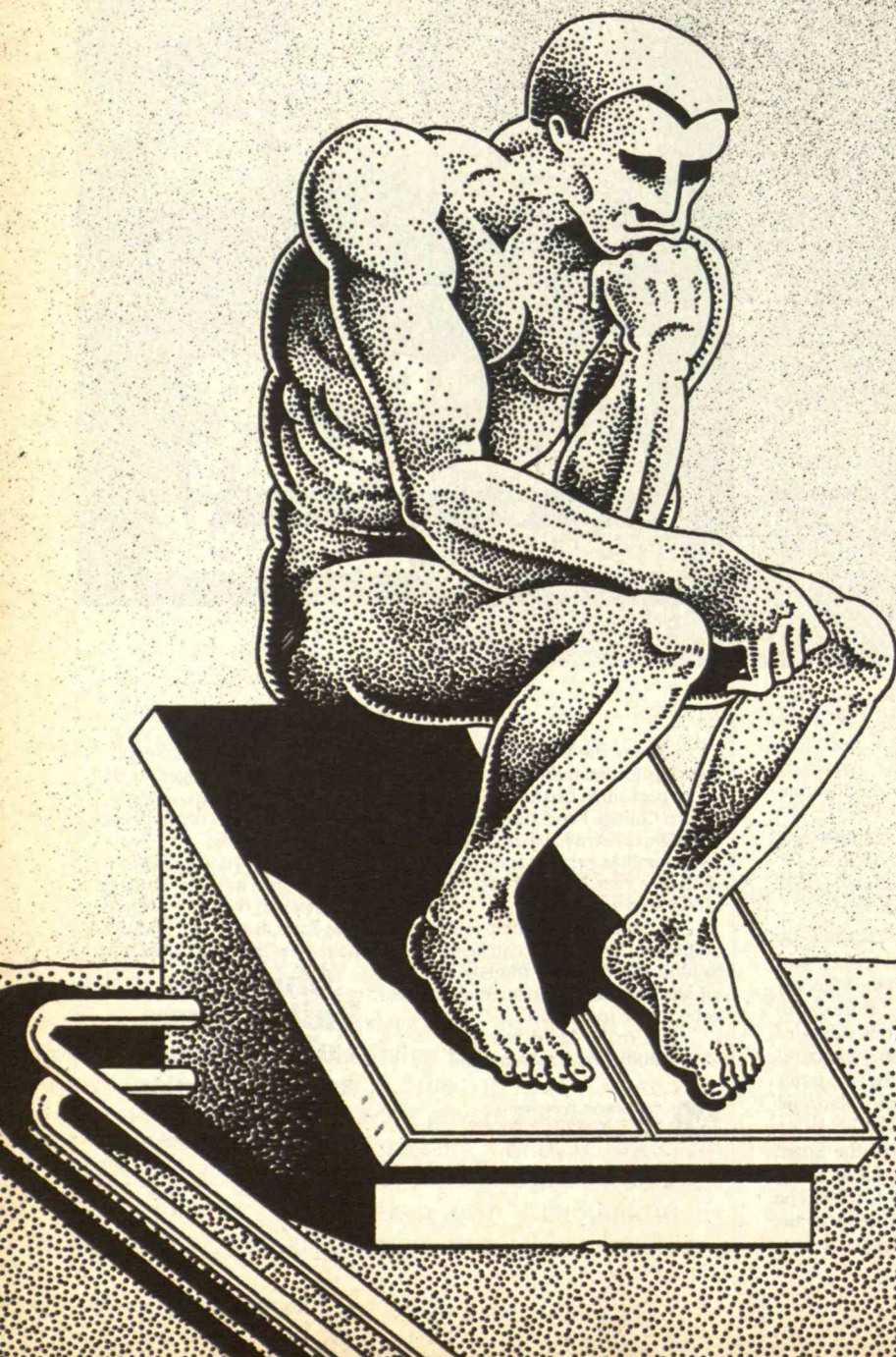
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Solar Technology:

BY KEVIN FINNERAN

SOLAR energy, often praised for its simplicity, is simple only in concept. Converting sunshine into useful and economical energy requires thoughtful engineering as well as strong public support. Photovoltaic cells, passive solar architecture, and solar water heating are already being used by millions of people, but each of these technologies is still in its infancy.

With the initial flush of excitement over solar energy fading, scientists and engineers are knuckling down to the hard work of lowering production costs, enhancing efficiency, and improving reliability. Despite a weak economy and diminishing government support, existing technologies are steadily improving and



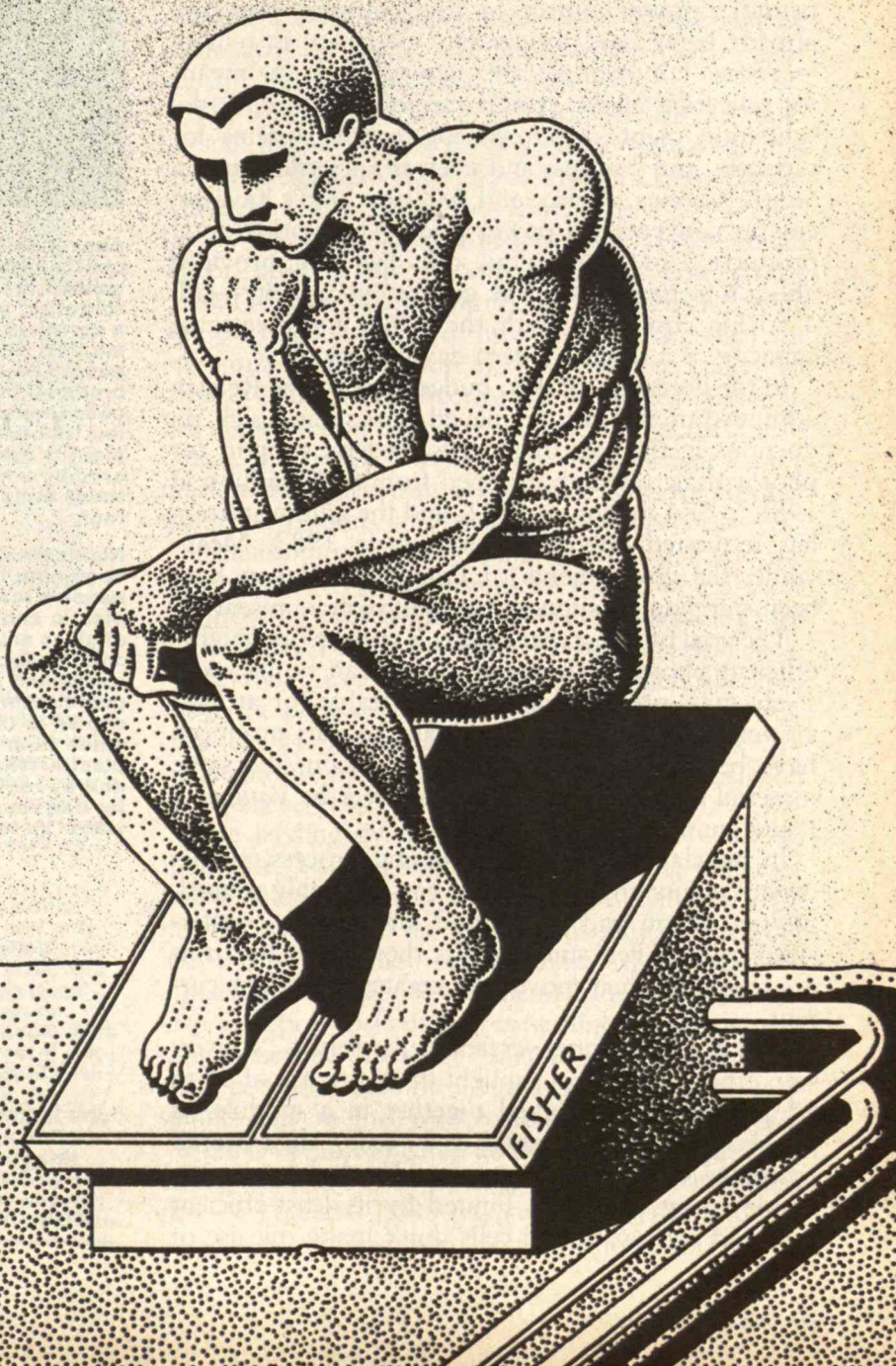
A Whether Report

new approaches are proving themselves. The news is not just how much solar technology is advancing, but in how many ways.

The Great Soft Hope

Photovoltaics (PV) are the great soft hope. Advocates of the "soft energy path" promote photovoltaic electricity as the leading alternative to nuclear power. But just as nuclear power was oversold by its early supporters as a ready source of "electricity too cheap to meter," so photovoltaic cells could also be overrated. Right now, the market lags behind expectations, and the technology is still evolving.

In 1975, the Department of Energy projected that by 1986 photovoltaic cells could be selling for as little as 70 cents per



peak watt—a price competitive with conventional power sources. Paul Maycock, director of the Department of Energy's photovoltaics program during the Carter administration, now predicts that PV cells will cost about \$4 a peak watt in 1986, compared with about \$10 a peak watt today. Maycock notes, however, that costs of conventional electric power have also risen faster than expected; \$4 a peak watt could be a competitive price in 1986.

While PV cells are still too expensive to become a primary power source in this country, they are already being used to generate electricity in remote locations. For example, they now provide the means for powering buoys, remote microwave stations, desalination plants, electronic protection systems for pipelines and bridges, and even rural settlements in South America, Africa, and Asia that don't have access to conventional power grids. The world's total production of photovoltaic cells last year provided about 6 megawatts of peak generating capacity—still a trickle compared with the 1,000 megawatts of capacity of a single modern-day coal plant.

In the domestic market, budget cuts by the Reagan administration have dampened hopes for quick reductions in the cost of PV cells. Federal support for photovoltaic research dropped from \$147 million in 1980 to \$74 million in 1982, and the administration has requested only \$27.6 million in 1983. Meanwhile, the governments of France and Japan have been stepping up support for photovoltaic research.

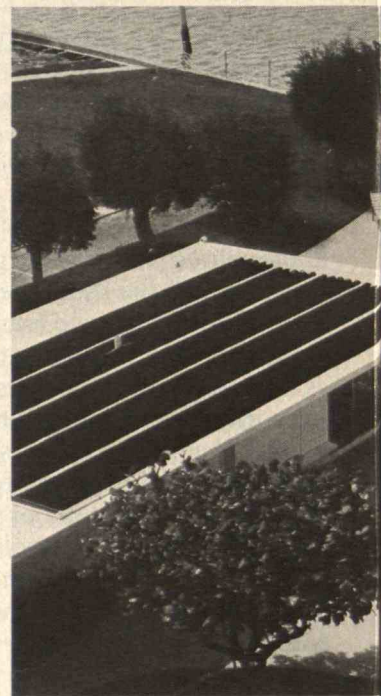
The goal of researchers today is to develop a highly efficient photovoltaic material that can be inexpensively mass-produced and remain stable for at least 20 years. Until now, virtually all the cells produced have been made of single-crystal silicon, the same material used in the cells that powered the *Vanguard I* satellite in 1958.

In an elaborate, time-consuming process, single-crystal ingots are pulled from vats of highly refined, molten silicon and then sliced into round, coaster-sized cells. When sunlight hits these cells, electrons are freed and their movement creates an electric current.

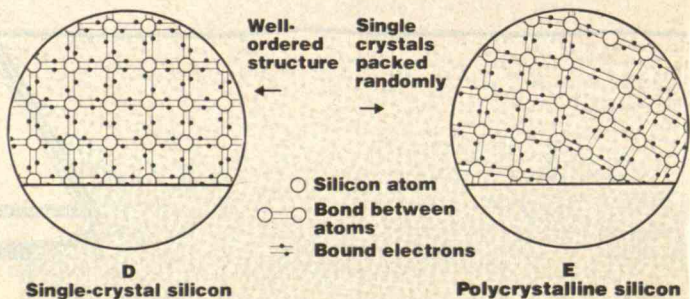
Today's finest single-crystal cells yield a "conversion efficiency" (from sunlight to electricity) of 16 to 17 percent. When linked together in a module—a panel containing an average of 40 cells—their overall efficiency drops to 10 percent. That's because the whole string of cells is limited by its least-efficient cell, and because round cells don't make full use of

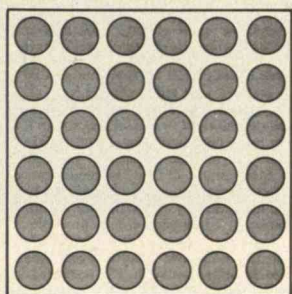
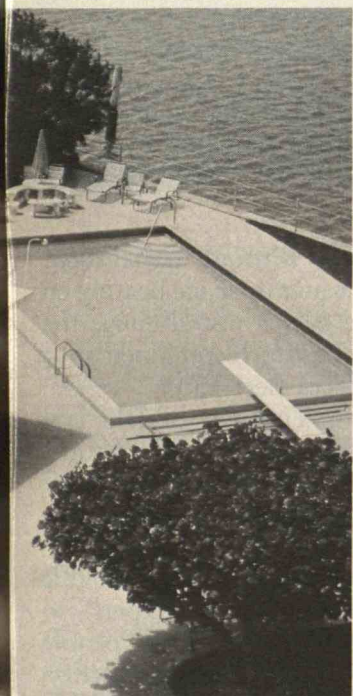
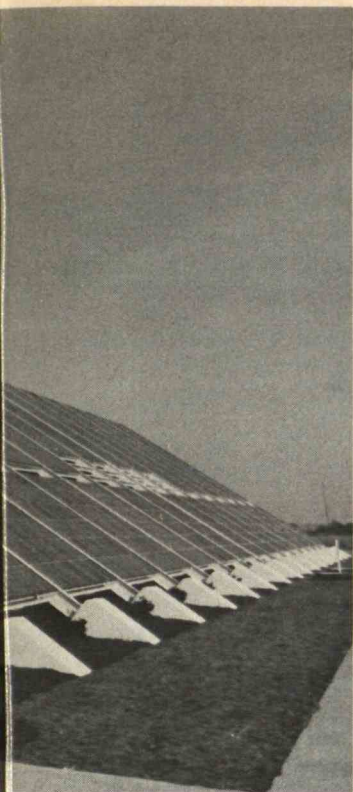


Above: Solarex Corp. recently completed the world's first solar-powered "breeder" plant. Located in a cornfield outside Frederick, Md., the plant is expected to manufacture—or breed—3,000 photovoltaic cells (made of polycrystalline silicon) a month. The plant is completely powered by a huge array of these cells on a slanted roof.

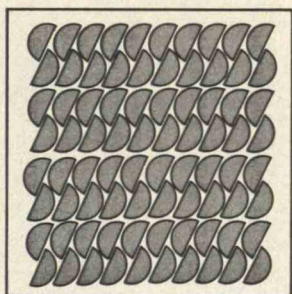


Right: Manufacturers are beginning to use less expensive materials (such as plastic and rubber instead of glass and metal) to build solar collectors for heating swimming pools. The pool-heating collector shown in this photo was made from a roll of flexible plastic. Attached to a nearby rooftop, the collector can readily heat pool water up to 100°F.

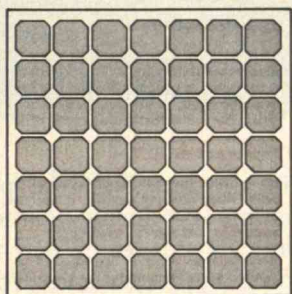




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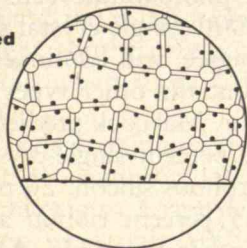


C

Above: The more photovoltaic cells packed into a panel, the more electricity it can produce. In A, standard round cells waste valuable space. In B, dead space is reduced by cutting cells in half. In C, square cells allow greatest use of the area but are more expensive.

Left: Photovoltaic cells were originally made only from single-crystal silicon, D, whose atomic structure forms an orderly pattern. Less costly to produce, polycrystalline silicon, E, is made of single-crystal patterns packed randomly. In amorphous silicon, F, atoms bond at random angles. Because of its uniform structure, single-crystal silicon most efficiently converts sunlight into energy, but is also the most expensive to produce.

Disordered structure



F
Amorphous silicon

the panel surface. Additional losses occur when the cells are arranged in a group of modules, when the voltage and amperage is being adjusted, and when electricity is being stored. As a result, a well-designed system of single-crystal cells has an efficiency of only 6 to 9 percent and a price tag of \$15 to \$20 per peak watt.

Although costs could fall with production improvements, many researchers believe no single-crystal cell can ever be cheap enough to dominate the market. Cheaper silicon ingots and cleaner slicing techniques may help, but the best opportunities for substantial price reductions lie elsewhere.

The obvious shortcut in manufacturing single-crystal silicon cells is to skip ingot formation and slicing altogether. Mobil-Tyco Energy Corp., Energy Materials Corp., Motorola, IBM, and Arthur D. Little are all working on a process that forms molten silicon directly into ribbons of almost pure single-crystal silicon. These ribbons, up to two inches wide and only a hundredth of an inch thick, are then cut into squares. In addition to being easier to make, the squares make more effective use of module space. So far, these ribbon cells have reached 12 percent efficiency, but production costs are still too high for the market. The quest now is to reduce costs by producing wider ribbons and speeding up the process.

Other companies are taking different paths to decrease costs. Westinghouse uses a special web process for growing cells from a molten liquid base to produce sheets of silicon with 16 percent efficiency. Honeywell dips a ceramic plate into molten silicon to cover the plate with a thin film of single-crystal silicon. The Honeywell cells are about 10 percent efficient and use only about one-fourth as much silicon as the sliced cells.

One leading pv manufacturer—Solarex Corp. of Rockville, Md.—recently began producing polycrystalline solar cells (composed of more than one crystal) for commercial use. These cells require silicon of less purity, but they cannot match the conversion efficiency of single-crystal silicon. However, the lower production costs of polycrystalline cells may more than offset the difference. Solarex is so convinced of their potential that the company is using polycrystalline cells to fuel the world's first solar-powered "breeder" plant. Located in a cornfield outside Frederick, Md., this new plant is expected to manufacture—or breed—3,000 polycrystalline cells a month—using power generated only by a huge rooftop ar-

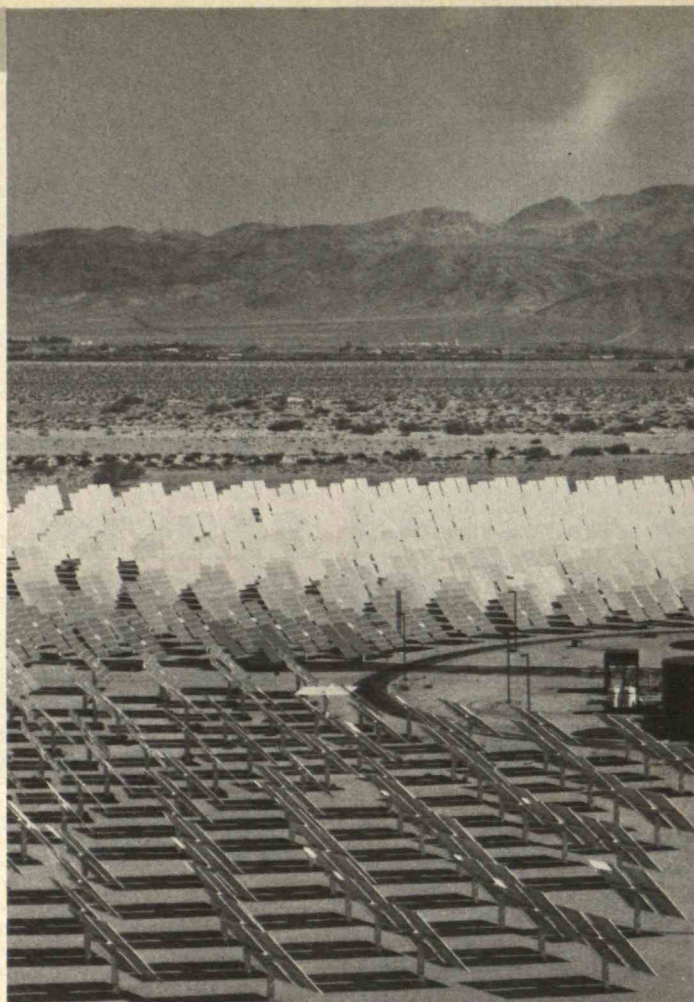
ray of these cells.

Still other companies, including some large Japanese firms, predict that amorphous silicon cells (those having no regular crystalline structure) will win the PV price war. While commercially produced amorphous cells are only 4 percent efficient, they are very inexpensive to produce, and improvements in efficiency are on the way. RCA recently announced that its research team had achieved 10 percent efficiency with amorphous-silicon cells. RCA says more research is needed before commercial production can begin, but Japanese competitors Sanyo and Sharp are now making amorphous-silicon cells for battery chargers, digital watches, and pocket calculators. While such solar-powered devices are still novelty items in the U.S., they are taken more seriously in the developing world, where battery supply is unreliable.

Last spring, the Chronar Corp. of Princeton, N.J., introduced the first commercial full-sized amorphous-silicon module. The Chronar modules sell for about \$6 per peak watt—a full one-third less than the going price of single-crystal silicon units—but the cells have not yet proven their durability. The Princeton firm sold only 100 kilowatts of amorphous-silicon cells in 1982, and the company can expect tough competition from the likes of Energy Conversion Devices of Troy, Mich., which is building a plant capable of producing 3 megawatts of amorphous-silicon cells a year.

Some researchers believe amorphous-silicon cells could be assembled with other cell materials in a "cascading cell" to further improve their efficiency. Cascading cells reflect the basic principle that different photovoltaic materials are charged by different wavelengths of light. With several layers of different materials in a single unit, "cascaded" cells can take advantage of a broader range of wavelengths from the sun, increasing the rate of conversion from sunlight to electricity.

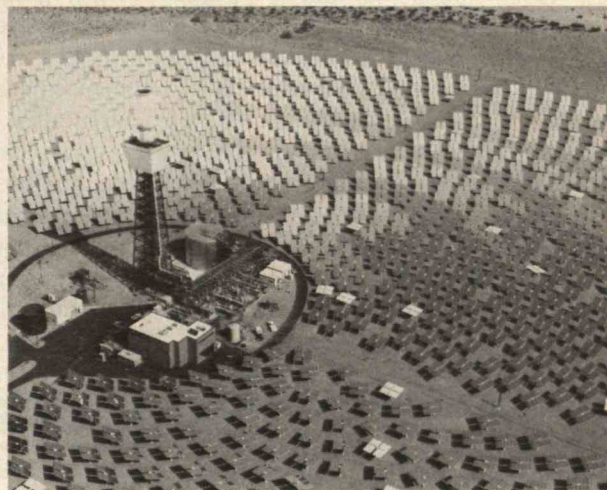
The wild card in the PV race is Texas Instruments, which has been working since 1974 on a hybrid photovoltaic system that furnishes usable heat as well as electricity. The system includes a large PV cell composed of thousands of tiny single-crystal silicon spheres imbedded in a glass matrix. This "electric sandpaper," which boasts a conversion efficiency of 13 percent, is immersed in an hydrobromic-acid solution. The electric current generated by the cells breaks down the acid solution into hydrogen and bromine. The hydrogen is stored as a metal hydride,



and the hot bromine passes through a heat exchanger, producing heat for water or space heating en route to storage. When the sun is not shining, the stored hydrogen and bromine are recombined in a chemical reaction that produces electricity.

Executives at Texas Instruments report their system is still five years away from commercial production. The federal government recently ended its support for the research, but the company plans to continue with its own money.

Everyone wants to know how fast the photovoltaic market will grow, and you can find an "expert" to tell you whatever you want to hear. Many people working in the PV industry predict that production will total 200 megawatts of photovoltaic cells in 1990 and 800 megawatts in 2000. Single-crystal silicon cells, observers generally agree, will continue to lead the market until 1990, but the other types of cells should gradually gain favor. Maycock predicts a 1990 market that is 30 to 35 percent single-crystal silicon, 20 to 25 percent amorphous silicon, 20 percent semicrystalline silicon, 15 percent ribbon and sheet silicon, and 5 percent other materials. After 1990, when the market is expected to expand dramatically, anything is possible.



When dawn breaks over the Mojave Desert near Barstow, Calif., 1,818 giant mechanized mirrors tilt upward to face the rising sun. The mirrors direct sunlight to a 300-foot tower, where water is heated into steam that, in turn, generates electricity in a turbine. The towers and mirrors belong to "Solar One," a new 10-megawatt plant that generates electricity for 6,000 homes.

Capturing Sunlight by Passive Design

Passive solar technology is at least 3,000 years old. Roman baths, pre-Colombian cliff dwellings, Navajo hogans—all these ancient structures were designed to capture and redistribute the sun's heat by non-mechanical means. The concept is no different in the passive solar homes of today.

Many of the first passive solar homes of the 1970s created a high-desert climate—torrid by day and frigid by night. The critical task of finding the proper ratio of window area to storage capacity was a guessing game for passive solar pioneers. And some of the designs that performed well called for placing thick masonry walls or racks of 55-gallon drums of water behind the south-facing windows, thus blocking the bright southern exposure that had attracted many homeowners to passive solar architecture in the first place.

Today computer programs can take the guesswork out of sizing windows and storage areas, enabling architects to adapt designs to local climates. While there were only 500 passive solar homes in 1978, between 60,000 and 80,000 such homes have been built since then, according to David Johnston, former

director of the Passive Solar Industries Council. A survey of owners of passive solar homes, conducted by the Northeast Solar Energy Center in late 1981, indicates that architects have learned their lessons: 91 percent of the owners were "very satisfied" with their home's energy performance; 95 percent said they would purchase a solar home again.

Although experience and improved computer models have done the most to make passive solar design reliable and attractive, various new products for heat storage are also easing the way for designers and owners of passive solar. One promising alternative to concrete, rockbeds, and water is chemical heat storage. These systems capitalize on phase-change materials that change from solid to liquid when they are exposed to the sun and absorb heat; they then release heat when they "refreeze" at night. Such materials can store four times as much energy per unit of volume as water. Thus, they are a lightweight, compact storage medium for passive solar design. The most practical compounds for home use are salt solutions such as calcium chloride hexahydrate and sodium sulfate decahydrate (Glauber's salt) that melt at about 80°F.

Adapting the principle of phase change to home

heating is not easy. At least 80 percent of any phase-change material must melt and freeze on a daily cycle if the system is to work effectively. Accordingly, containers must be relatively flat to provide maximum exposure to the sun. The containers must also be durable—puncture-proof, corrosion-resistant, and heat-conductive. Another problem is the chemical instability of the salt solutions, which can break down gradually over a year or two. Long a major drawback, this problem is being corrected by adding stabilizers that lengthen the solutions' life but that also lower heat-storage capacity.

Paul Kando of the National Association of Home Builders Research Foundation admits that builders today have a hard time finding phase-change materials in forms they can easily incorporate into conventional buildings. But he believes systems using these materials can be dramatically improved as chemical manufacturers, container makers, and builders develop phase-change units that will be inexpensive and easy to use. Once the housing market recovers, Kando expects to see such units installed in 250,000 new passive solar homes each year.

A more familiar technology—movable window insulation for cutting nighttime energy loss—was left to the do-it-yourselfers until a few years ago. Now a vast array of thermal drapes, shutters, and shades to go inside, outside, or even between the panes of double-glazed windows (those with two layers of glass) are available, and many of these products are designed specifically for passive solar houses. Steve Baer of Zomeworks in Albuquerque, N.M., has come up with two of the most innovative designs. One is a rigid cover for skylights, called Skylid, that is operated by solar-activated freon pumps. The other has a photosensor-triggered pump that shoots foam pellets into the space between double-glazed windows at night and sucks the beads out when the sun shines.

An alternative to covering windows is to reduce heat loss through the glazing. The Southwall Corp. of Palo Alto, Calif., produces a transparent film called Heat Mirror, with a thin metallic coating that transmits sunlight almost as well as glass does. The coating also reduces heat loss by reflecting back into the room 85 percent of the thermal radiation. The usual application is to replace the middle layer of glass in a triple-glazed window with Heat Mirror.

Airco Temescal of Berkeley, Calif., has developed a process for applying a transparent metal coating directly to glass to reduce heat. Airco originally used a

coating of indium tin oxide that is durable but prohibitively expensive. Now Guardian Industries of Carleton, Mich., is experimenting with a copper-based coating that promises to be economical but that doesn't yet meet standards for durability.

Researchers are conducting interesting experiments with selective coatings overseas. The Japanese use a form of heat mirror in the glass doors of display freezers and refrigerators in supermarkets. England's Pilkington Glass Co. is marketing a coated glass based on Airco Temescal's technology. In Europe, heat loss is cut by filling the space between double-glazed windows with argon, a conduction-resistant gas. Leakage of gas, however, is a problem with the European approach.

The "supply-side" approach—increasing the amount of incoming sunlight—also has its defenders. Glass ordinarily transmits only about 84 percent of the sun's energy, so independent laboratories and glass manufacturers are now working on window coatings that would reflect less energy and admit more. For example, the 3M Corp. manufactures a Sun Gain film that transmits 93 to 96 percent of the sun's energy, and General Glass International makes Solar Kleer, a low-iron glass that transmits 90 percent. Both cost more than ordinary glass, and the economic advantage must be calculated for each specific situation.

Coating that reflects heat back into the room may work best on north-side windows, while high-transmission glazing may be the answer when the goal is to maximize solar gain. Steven Selkowitz, a staff scientist at Lawrence Berkeley Laboratory, is developing a computer program to help designers compare the potential of individual products for each particular case. If architects and designers had a quick reliable way to balance trade-offs among solar gain, heat loss, and cost, says Selkowitz, new solar technologies could eventually make a far more significant contribution to energy savings.

New Ways to Heat Water

Solar water heaters are the old, familiar workhorses of solar technology. Most of these mechanical devices rely on large roof-mounted panels that collect sunshine, convert it into heat, and transfer the heat to water. The water is either used directly as a hot-water

(Continued on p. 57)

A Superinsulated Year

By Mark Hyman, Jr.

IN 1980 I engineered and had constructed a superinsulated passive-solar house in Winchester, Mass., a north-western suburb of Boston. While a number of superinsulated houses have been built, mostly in Canada, they are usually designed with few windows. My design combined superinsulation with a substantial area of windows facing south.

Completed in April 1981, the house was promptly occupied by tenants who agreed to let me observe its performance. My objective was to compare the costs versus the benefits of this unusual design.

The two-story, five-room house is medium-sized, with 1,500 square feet of living space. It has no wood stove or fireplace. The auxiliary heat is electric, making its monitoring as simple as reading a meter.

Visitors enter the house through a glass-enclosed 8-by-15-foot sunspace on the south side. The sunspace is equipped with several large containers of water to help keep the space warm. When the temperature in this sunspace exceeds 75°F, a thermostatically controlled fan moves the warm air into the rest of the house.

The entire house is double-walled and heavily insulated. Triple-glazed windows are used throughout except on the south side, which has double-glazed windows. All but the sunspace windows are fitted with built-in shutters that can be moved on tracks into the inner walls. Auxiliary heat is provided by a six-foot, 1.5-kilowatt baseboard unit with individual thermostats in every room.

In addition to these space-heating features, four solar-collector panels are used to



Mark Hyman, Jr., took the saltbox approach in designing this superinsulated passive-solar home in Winchester, Mass. Its

most attractive feature is a glass-enclosed sunspace, inside which four translucent containers of water store heat.

heat domestic hot water, with an electric hot-water heater as backup.

My initial calculations were aimed at comparing the heating requirements of my superinsulated passive-solar house with those of a conventional new house. First, I had to gauge the severity of the Boston winter, which can be measured in degree-days—the difference between 65° and the mean outdoor temperature during a day.

For example, if the mean temperature of a given day is 25°, then there are 40 degree-days on that day. In Boston's western suburbs, there are about 6,500 degree-days per year.

For a conventional house with perhaps 50 square feet of south-facing double-glazed windows, I calculated that the total heat loss (or conversely, the amount of heat that must be supplied) would be about 13,000 Btus per

degree-day. (A Btu—or British thermal unit—is a standard measure of heat.) With Winchester's 6,500 degree-days per year, the total annual heat requirement of a conventional house would be 84 million Btus. Of this, some 66,000 Btus per day might come from internal heating (cooking, lighting, refrigeration, and the occupants themselves), and an average of 25,000 Btus would come as solar heat through the south-side windows. These sources might contribute 19 million Btus during the heating season, leaving a net demand of 65 million Btus (19,120 kilowatt-hours) to be supplied by heating systems.

Trapping the Heat Inside

In contrast, the gross heating demand of my superinsulated passive-solar house was 6,270 Btus per degree-day. I arrived at this figure by calculating the heat loss for the house per degree-day.

The entire house is built with two sets of walls separated by a 1-inch air space. The outer walls are framed with 2-by-6-inch studs spaced at 2-foot intervals, the inner walls with 2-by-4-inch studs spaced at 16-inch intervals.

The outer wall is sheathed with half-inch plywood covered with vinyl siding; the inner wall has 6-mil polyethylene between the studs and the interior drywall surface. There are two layers of fiberglass insulation rated at R-19 and R-13 (R is a measure of a material's thermal resistance). With all the wall components combined, resistance through the walls is R-35, with a heat loss of 1,200 Btus per degree-day.

The second-story ceiling contains 6-inch fiberglass insulation as well as a poly-

ethylene infiltration barrier. There is also 6-inch fiberglass insulation between the roof rafters. Thus, the total thermal resistance above the ceiling is R-40, permitting a heat loss of only 600 Btus per degree-day, with another 240 Btus through the garage ceiling.

The insulated shutters, when closed, provide thermal resistance of R-7. Total heat loss through the windows and shutters, when closed at night, is estimated at 1,310 Btus per degree-day. Fortunately, the residents were conscientious about closing the shutters at night and lowering the thermostat during sleeping hours.

The inside of the concrete basement walls has an insulation of R-7, and the outside of the wall is covered with two inches of styrofoam. The calculated heat loss of the walls was 320 Btus per degree-day.

I assumed that outside air amounting to one-third of the total volume of the house would be exchanged for inside air every hour, representing a heat loss of 1,810 Btus per degree-day. Passage of heat through the outer doors and concrete floor slab added another heat loss of 790 Btus per degree-day.

All these factors added up to an estimated total heat loss (or gross heat demand) of 6,270 Btus per degree-day—less than the half the gross demand of a conventional house. With 6,500 degree days per year, this yielded a gross heating demand of 41 million Btus per year.

I estimated that heat from internal sources (people and electric appliances for an average family) would total about 88,000 Btus per day, a total of 18.5 million Btus for the seven-month heating season. That would supply 45 percent of the gross heating demand.

The passive solar con-



tribution from the 75 square feet of south-facing windows for the same seven months would supply another 32 percent of demand. Sunshine during the rest of the year is superfluous, since internal sources supply more than enough heat to keep the house warm.

The sunspace contributes about 3 percent of the total heat—but only during the spring and fall. In mid-winter, most of the solar heat inflow is used to maintain the temperature of the sunspace during sunless periods. This is due to the fact that it has no insulating curtains and derives no heat from internal sources.

Solar heat is stored in the sunspace in a number of ways. Two 55-gallon drums and four translucent cylinders are filled with water. In addition, six dark-painted plastic tubes of calcium-chloride salts absorb heat upon melting at 80°F and then release

this energy upon refreezing. The floor of the sunspace is finished with tile and slate underlaid with six inches of concrete on six inches of crushed rock, two inches of styrofoam board, and a polyethylene sheet. This type of flooring is also a good medium for storing heat.

Finally, I estimated that only 20 percent of the gross heating demand would come from auxiliary heat. This would add up to 8 million Btus, or 2,350 kilowatt-hours, per year.

In reality, the additional electricity required to heat my superinsulated passive-solar house from May 1, 1981, to May 1, 1982, was 4,667 kilowatt-hours. That meant energy savings of 76 percent over a conventional house, and with electricity at 8.5 cents per kilowatt-hour, an actual savings of just over \$1,250. If oil at \$1.25 per gallon had been the source of auxiliary energy, the savings

would have been \$750 (assuming 60 percent efficiency). However, installing an oil burner and all its accessory equipment would have added about \$3,000 to the cost of the house, or \$500 a year at mortgage rates then in effect.

While an annual savings of \$1,250 is substantial, the results were somewhat disappointing, as I had calculated the annual auxiliary demand to be only 2,350 kilowatt-hours. So I set out to determine why my estimate did not better match the real-life outcome.

The Villain: Infiltration

How did real life differ from these assumptions? To begin with, the house was rented to a couple whose two children visited them only on weekends. So I revised my estimate of residents' contribution to heat, originally based on four occupants, to 12,000 Btus per day. Electricity from lights and appliances supplied only 16 kilowatt-hours (54,000 Btus) per day. Thus, internal heat sources contributed a total of only 66,000 Btus per day, rather than the 88,000 Btus I had estimated.

December 1981 and February 1982 were much cloudier than normal, both having less than two-thirds the normal sunshine. Furthermore, January was exceptionally cold, with an average of 47 degree-days of heating required per day, compared with the normal 39 degree-days per day on which I had based my calculations.

When I inserted all these factors into the equation, I calculated auxiliary energy consumption to be 3,600 kilowatt-hours, still appreciably below actual use.

Only one untested assumption remained: the rate of air infiltration. I found that actual heat consumption agreed with my computed (Continued on p. 71)

(Continued from p. 54)

supply or, in the case of space heating, circulated to heat the home.

Some of the solar water heaters built in the 1970s turned out to be unreliable and uneconomical. Owners complained about poor design and construction, shoddy installation, and inadequate service by what often turned out to be fly-by-night manufacturers. Since then, more established manufacturers have refined their basic products, and both reliability and installation are improving.

Now there is a new generation of water-heating systems that rely on more sophisticated materials and, in some cases, advances in technology. Pool-heating systems, which must heat water to no more than 100°F, were among the first systems to be revamped. Manufacturers realized that less expensive materials would be adequate, and plastic and rubber began to replace glass and metal. Bio-Energy Systems of Ellenville, N.Y., has developed what may be the simplest pool-heating collector—a roll of flexible plastic (ethylene-propylene-diene-monomer) with built-in tubing that can be fastened directly to a nearby roof and requires no cover.

Some of these innovations are now being adapted to domestic systems to heat water to 150°F. The important new ingredient is plastic. Researchers have developed plastic covers that are more resistant to scratching and degradation by the sun's ultraviolet rays, as well as plastic tubing that is more tolerant of high temperatures. Several companies are including these less expensive components in collectors.

Ramada Energy Systems has produced an all-plastic collector made with four polymers. The company claims the collector can withstand temperatures up to 300°F, completely resist degradation by ultraviolet light, and provide performance only 6 or 7 percent below that of a good copper collector. The price is as much as 25 percent lower than a conventional collector and the plastic collector also weighs much less—a boon during installation.

Meanwhile, Sunmaster Corp. of Corning, N.Y., makes collectors that produce temperatures of up to 250°F—high enough for many industrial processes. The pipes in Sunmaster's "evacuated-tube" collectors are encased in vacuum tubes that reduce heat loss, and a reflective backing works the other side of the equation, increasing solar gain. Though more expensive and fragile than ordinary collectors, evacuated-tube collectors require less space and are especially

valuable where sunlight is limited. Some experts have doubts about the market potential of such collectors for residential use, but Sunmaster's Joe Frissora is confident. "What we have is as different from flat plates as the internal-combustion engine was from the horse and buggy," he declares. "Flat-plate technology simply isn't going to get any better. I see it as just a matter of time before the whole solar collecting market changes radically."

Roger French of the Suntime Corp. in Bridgton, Maine, has taken yet another approach by manufacturing a passive phase-change water heater that circulates the refrigerant R-114, which vaporizes at 39°F. When the sun hits the collector, the refrigerant converts to a gas, which then rises to a heat exchanger. There the gas condenses, releasing the stored heat into the water. The liquid refrigerant is then recirculated through the collector. This pumpless, freeze-proof system is particularly suited for use in cold climates. Its major limitation is the fact that the collector must be lower than the storage tank, making roof mounting difficult in some cases. French has installed 150 of these systems in New England and claims that though the system is 10 to 15 percent more expensive than a typical straight-storage system, it will produce 30 percent more hot water.

An even more innovative approach to water heating is being pursued by Dmitri Tchernev, a former researcher at M.I.T.'s Lincoln Laboratories. The key to Tchernev's system is zeolite, a fine-grained mineral created by the reaction of salt water with volcanic ash. Zeolite releases water vapor when heated and absorbs it when cooled. Mounted behind the collector's copper absorber plate, the zeolite expels hot water vapor during the day that goes into a heat exchanger. Water is then piped through the heat exchanger, picking up heat from the water vapor. As the water vapor loses heat, it condenses. At night, the zeolite absorbs the water vapor and gradually reduces the pressure within the sealed system. As the pressure drops, the boiling point of water decreases, and the water in the collector in the heat-exchanger system evaporates. The evaporating water takes up heat, producing cooled water for air conditioning or refrigeration.

Tchernev is currently installing a zeolite system in a Denver home, where he expects it will provide all the cooling and water heating plus 65 to 75 percent of the space heating. A home system currently costs between \$40,000 and \$50,000, but Tchernev thinks

that mass-production will bring the price down to between \$12,000 and \$20,000, depending on the size of the home.

These experimental designs for heating water may mature, but only the conventional glass-and-metal collectors have been around long enough to afford surprise-free use. Installation of these systems has been simplified: the tricky plumbing and controls are preassembled, and manufacturers now supply racks for mounting collectors on roofs.

While solar water heaters are improving, exactly how good they are is unclear. With so many different solar collectors on the market, a straightforward means of comparing them would be invaluable, but none exists. Indeed, manufacturers of solar collectors have been trying to agree on a testing procedure to compare collector performance for years, but so far no consensus has emerged. While the Solar Rating and Certification Corp. and the Air-Conditioning and Refrigeration Institute jockey for control of collector testing, consumers hang back and the entire industry suffers.

Meanwhile, mechanical, or active, solar systems for space heating have been virtually ignored because of high costs. Active space-heating collectors resemble those used for water heating but cost about \$10,000 up front. Many people thought the day of active solar systems had arrived in early 1982, when General Electric announced that it had developed an air-circulating evacuated-tube collector three times as efficient as existing collectors. But GE's system will not be ready to go on the market for at least five years.

Active solar heating may get a needed boost sooner from solar-assisted heat-pump systems. The heat pump, which takes heat from the outside air and blows it into a house, is often regarded as a competitor to a solar system, but this need not be so. Heat pumps work efficiently only when the temperature stay above 25°F, so in cold climates they must be linked to the earth or groundwater, which usually stay warmer than the air. Using solar energy to pre-heat the heat source for the pump improves its efficiency and makes it easier to use in colder climates. Researchers are aiming to perfect a hybrid system that will provide heat, hot water, and air conditioning. According to New York market consultants Frost and Sullivan, the boom in solar-assisted heat pumps will make such solar systems a \$6 billion-a-year industry in the year 2000.

The Industrial Uses of Solar

While the technology for using solar energy to heat swimming pools and household water is already established, the means for harnessing solar energy for industrial use is still in its early years. And high-temperature systems for generating electricity are facing their first commercial-scale test.

For instance, in 1982 the Department of Energy (DOE) launched two major projects designed to demonstrate the feasibility of high-temperature, or solar thermal, systems. One of these projects, which relies on a field of 114 giant parabolic (bowl-shaped) solar collectors, has already begun generating electricity and industrial process heat in Shenandoah, Ga. The dishes, adjusted to follow the sun across the sky, concentrate and reflect sunlight onto a focal point, producing the equivalent of 234 suns of power. The concentrated energy is sufficient to liquify silicon at 750°F, and the hot silicon superheats steam that drives a turbine generator, producing electricity for a nearby knitwear factory. Meanwhile, steam extracted from the turbine at 350°F is piped to the same factory to be used to press clothes. Steam exhausted from the turbine can also be used to power the factory's air-conditioning system.

Project manager Ed Ney, of Georgia Power Co., which is directing the project for DOE, reports that the research facility meets all expectations for producing power. It produces an equivalent of 3 megawatts of power, which yields 400 kilowatts of electricity, 1,380 pounds per hour of 350°F steam, and 257 tons of air conditioning. Still in the research phase, the plant is not meant to compete with conventional power.

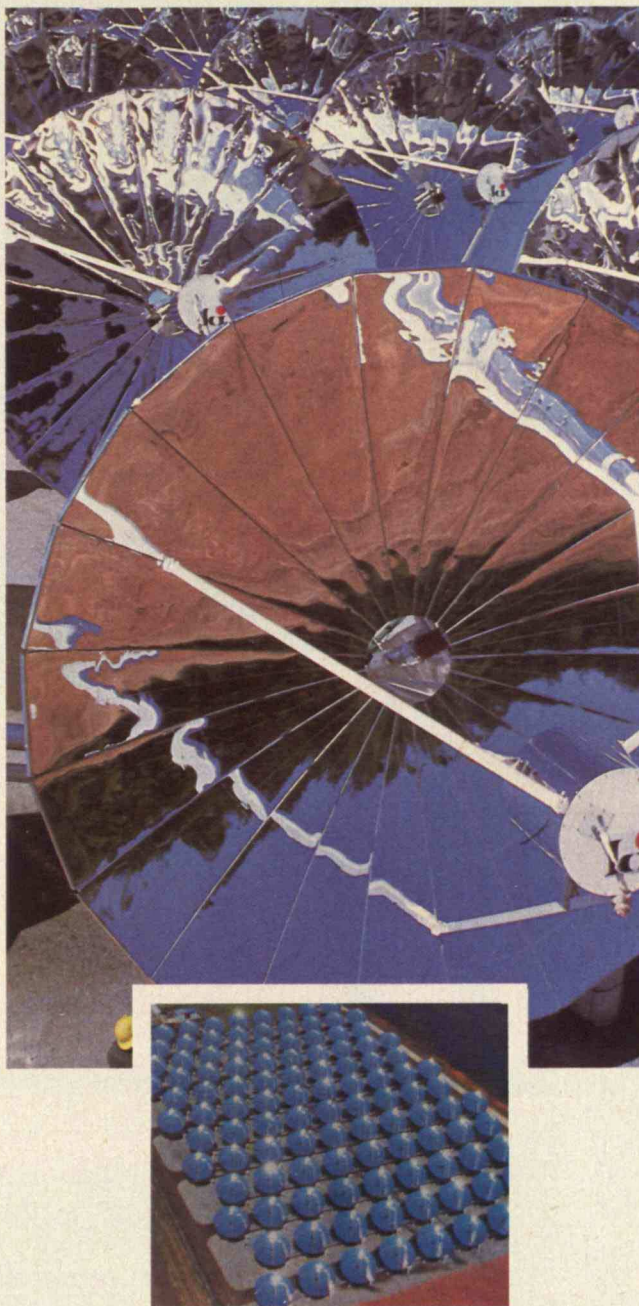
The DOE's Solar One "power tower" embodies another promising approach to generating electricity with solar energy. Built in the Mojave Desert near Barstow, Calif., at a cost of \$14 million, Solar One is the world's largest solar power plant. The new 10-megawatt plant reflects sunlight from 1,818 heliostats (giant mechanized mirrors with a surface of 40 square meters) onto a water-filled receiver mounted on a 300-foot tower. The water is heated until it becomes pressurized steam inside the receiver. The steam, in turn, generates electricity in a turbine for up to 6,000 homes in Southern California Edison's power grid. So far the plant is generating electricity for up to 12 hours a day. SCE officials are now planning to build a much larger 100-megawatt plant dub-

bed Solar 100.

As a research facility, Solar One cannot begin to compete with conventional power plants. But utility officials estimate that when Solar 100 is completed in 1988, it will be competitive with coal and oil operations. Although startup costs may be higher than those of conventional plants, the lack of fuel costs should make it economically feasible.

Despite high costs, other investors are convinced that large-scale technology for electricity is ready for the market. Acurex Corp. of Palo Alto, Calif., was prepared to build a 12-megawatt power plant using parabolic dish collectors until reluctant investors put the project on hold. Acurex still plans to complete the plant and sell electricity to Southern California Edison. Luz Engineering will build and operate a 15-megawatt solar thermal plant in Southern California that will use Israeli parabolic trough collectors. Both Acurex and Luz expect to turn a profit with no federal support except for the investment and solar tax credits.

Innovative financing arrangements now enable third-party investors to sell energy from large low- and medium-temperature solar systems to industrial facilities, stimulating the industrial solar market.



A field of glittering, bowl-shaped solar collectors in Georgia is the Department of Energy's first major attempt to harness solar energy for high-temperature industrial use. The huge dishes, 114 in all, reflect sunlight onto a focal point, heating sili-

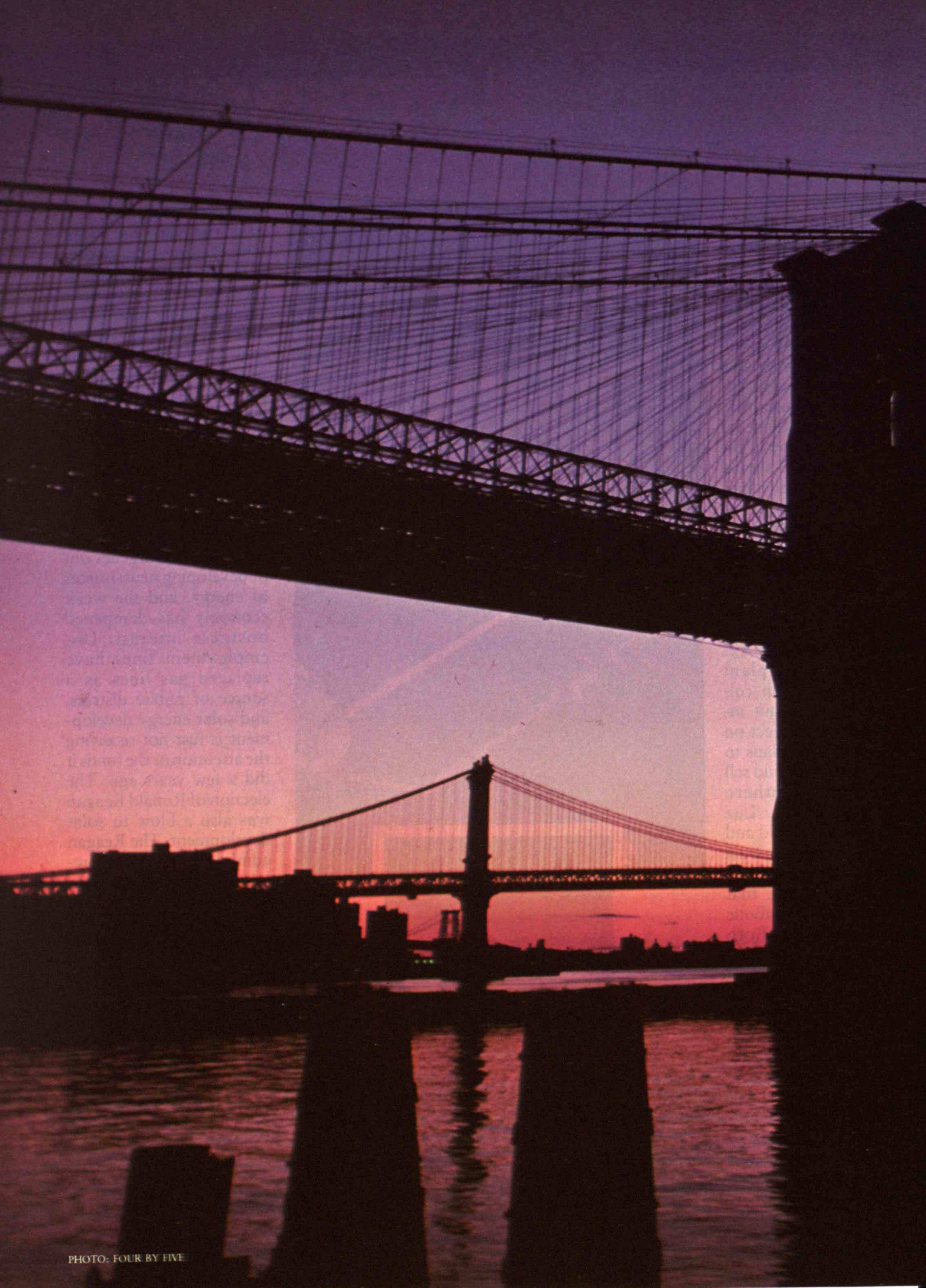
con to 750°F. The silicon superheats steam that drives a turbine, producing electricity for a nearby knitwear factory. The steam is then extracted and used to press clothes as well as to power the factory's air-conditioning system.

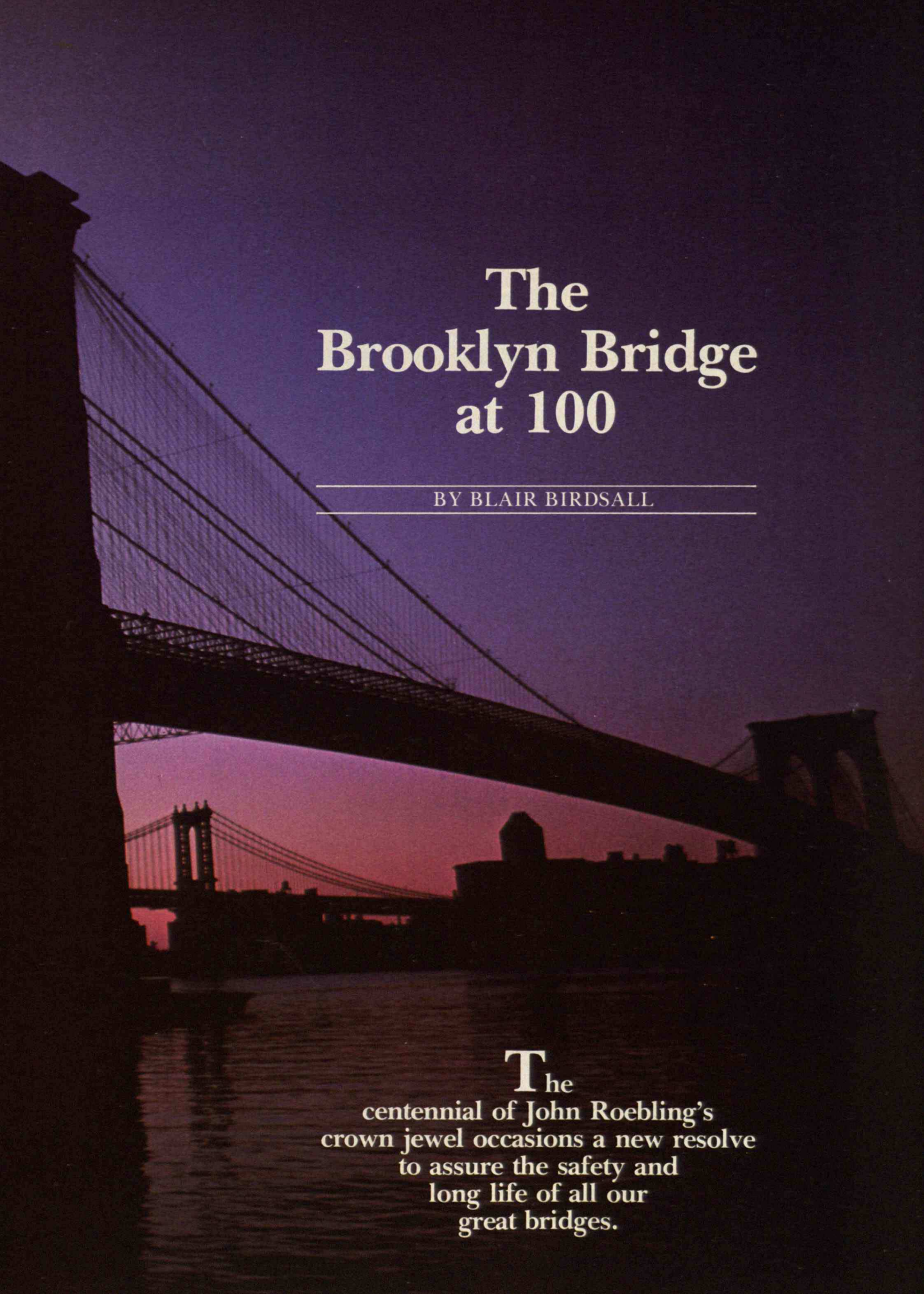
Such financing will also ease the way for high-temperature solar electric systems as they become economically competitive. Though many solar advocates are put off by the size and complexity of these power towers, they may prove to be one economical and environmentally sound means of generating electricity.

Overall, solar technology is not yet cheap enough to attract widespread investment. Stable oil prices have taken the urgency out of developing new sources of energy, and the weak economy has dampened business interest. Unemployment lines have replaced gas lines as a source of public distress, and solar energy development is just not receiving the attention or the funds it did a few years ago. The election of Ronald Reagan was also a blow to solar development. The Reagan administration has cut research funds for solar energy from \$633 million in 1980 to \$268 million in 1982, and has requested only \$73 million for 1983.

The future pace of solar progress will continue to depend as much on these political and economic factors as on the ingenuity of scientists and engineers worldwide.

KEVIN FINNERAN is editor of *Sun Times*, the magazine of the Solar Lobby in Washington, D.C.

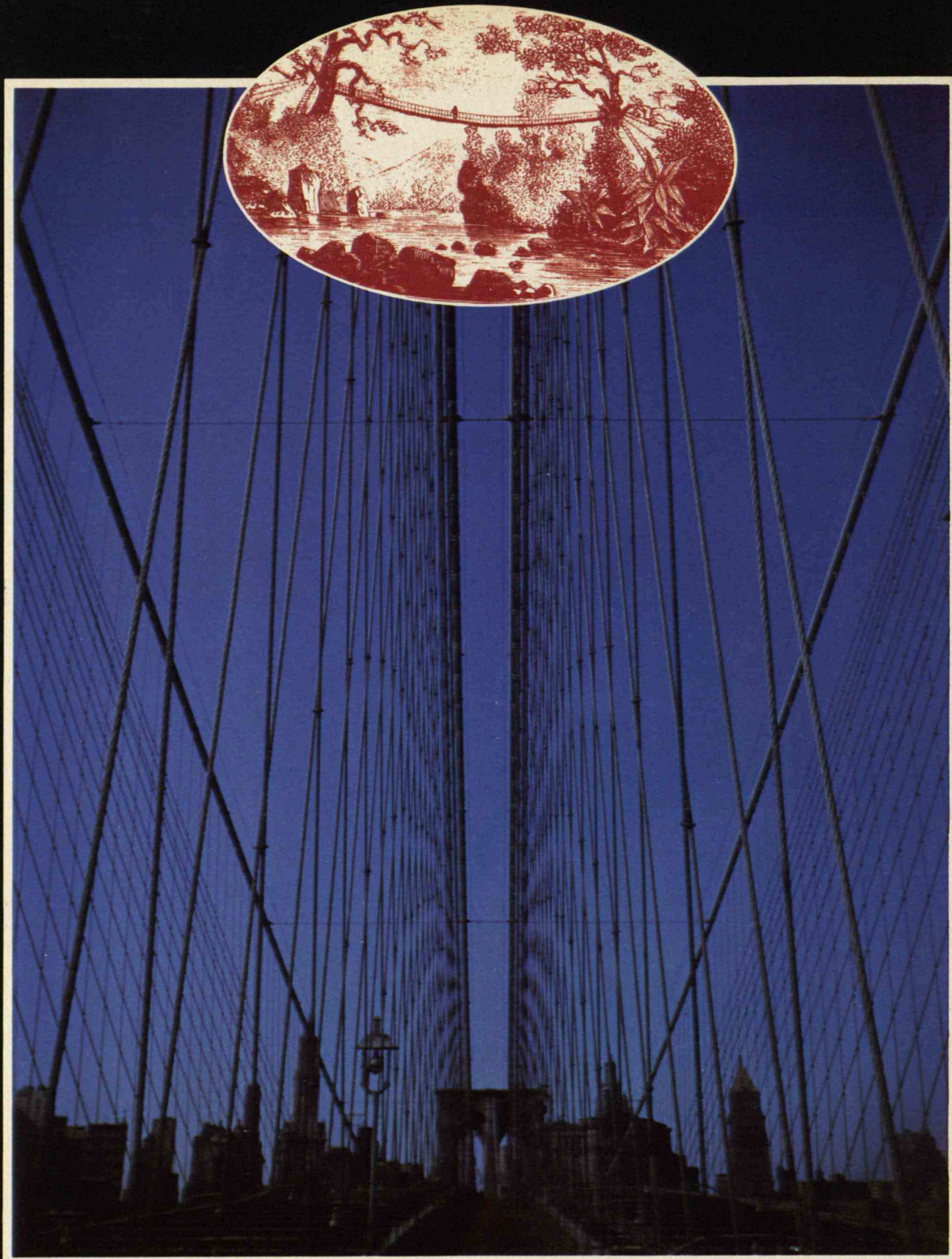




The Brooklyn Bridge at 100

BY BLAIR BIRDSALL

The
centennial of John Roebling's
crown jewel occasions a new resolve
to assure the safety and
long life of all our
great bridges.



The first suspension bridges sagged in the middle because the platform followed the natural curve of the cables. The bold step of hanging a level platform brought new problems of stability, which Roebling solved by adding the diagonal cables shown in this photograph. His Brooklyn Bridge displays 16 fans of such diagonals linking roadway and towers.

JOHN Roebling, the creator of the Brooklyn Bridge, is unique among bridge builders. He was the only one in the early nineteenth century, when modern suspension bridges first appeared, who never let fashion or untested theories eclipse his basic common sense. While others around him built suspension bridges that became famous for blowing down in the wind, his bridges have gone out of service only because of obsolescence. Roebling's largest and most famous design is as viable and sound today—except for repairs to restore the materials to their original condition—as the day it was inaugurated in May 1883.

To appreciate the dimensions of his genius, Roebling's achievements must be put in the context of what was going on elsewhere in the field of suspension bridges. It was a time of experimentation. Many fine, intelligent engineers applied themselves to this field. But many, taking steps that they believed were based on experience or elementary attempts at new theory, found that their steps were too large or even in the wrong direction. Roebling's hand was singularly sure.

Rope-Borne Catwalks to Steel-Borne Highways

During Roebling's active career, roughly from 1830 to 1870, suspension bridges in the modern sense—structures with a relatively horizontal travel-way supported from overhead cables—were just beginning to gain wide attention. In contrast, in previous suspension bridges the platform had been directly connected to and followed the curve of the cables. (Roebling died just as construction of the Brooklyn Bridge was beginning, leaving supervision to his son.)

It was clear to many designers that the suspension bridge was then the only means available to span distances required for crossings such as New York's East River. But while Roebling was drawing his conservative plans for the Brooklyn Bridge with a record span of 1,600 feet, other designers were increasing span lengths without Roebling's intuitive sense for stability, despite the fact that many suspension bridges in the United Kingdom and the United States had been destroyed by wind. Roebling also uniquely recognized the value—in terms of strength, stability, and economy—of a single cable mass. While others called for large cables composed of several small ones laid side by side, Roebling's cables were designed to become a single, compact bundle.

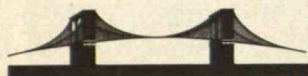
By the end of the nineteenth century, most engineers had come to agree with Roebling's sense of the need for stiffening structures on a suspension bridge. In response, a mathematical theory was developed by the Austrian bridge designer Joseph Melan to analyze a stiffened suspension bridge. The first to be designed on the basis of this theory was the Manhattan Bridge, built during the first decade of the twentieth century. The theory was successful, and stiffness has been recognized ever since as essential in suspension bridge design. Indeed, many bridges were overdesigned in this respect, with the result that the structures were heavier and more expensive than necessary. But this fault can be excused in the first application of the new theory.

Other problems, however, have made the other East River suspension bridges less distinguished in maturity than Roebling's. These problems include the selection of materials, erection methods, and the balancing of dead loads (the weights of the bridge structures). One example is the use of nongalvanized wire on the Williamsburg Bridge. Another is the failure, in the design of the Manhattan Bridge, to account for the fact that two of the four identical cables were located so that they should carry more dead load than the other two. Because the cables were designed for equal loads, the actual load had to be distributed to the four cables by means of the floor-beams, which were not really designed for that purpose.

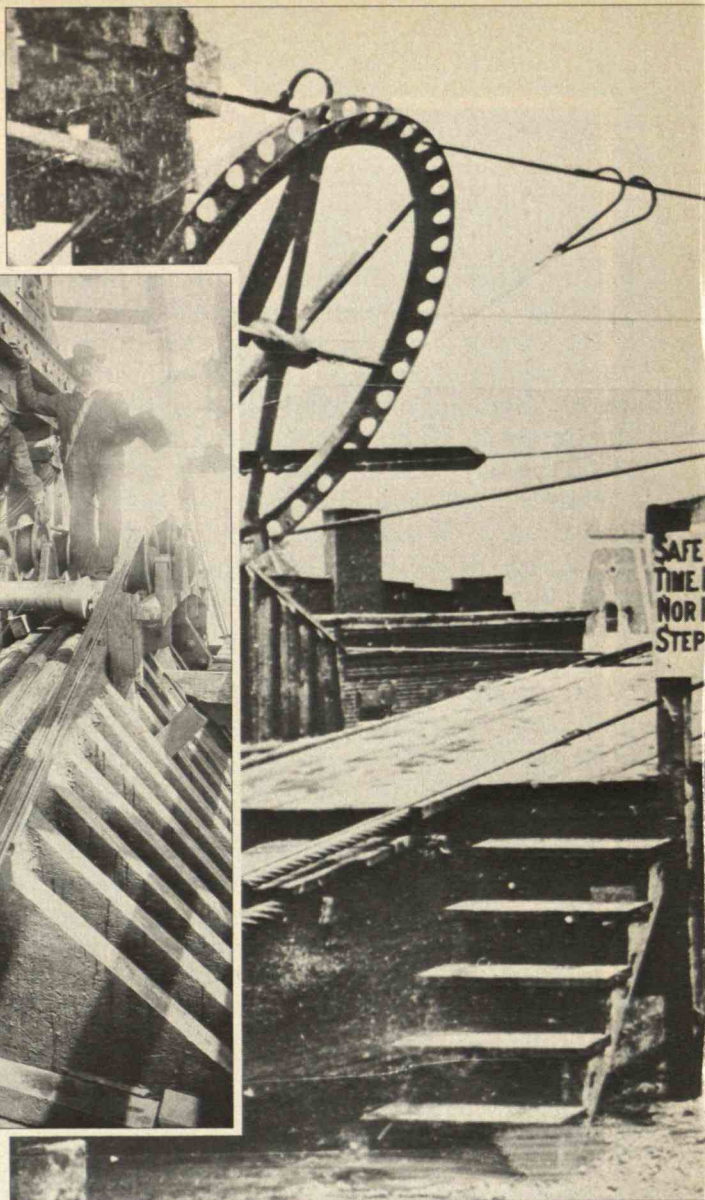
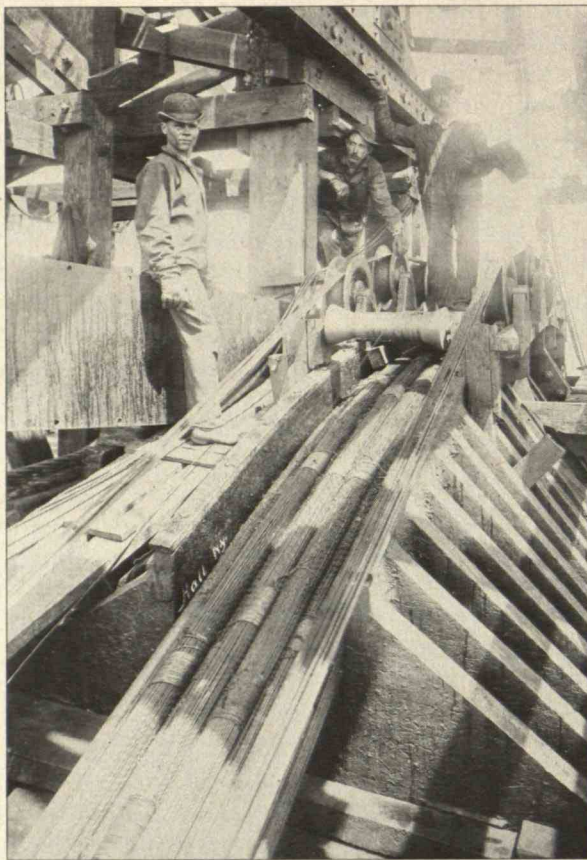
By the early 1920s, when engineers had gained experience and confidence in using the new theory, stiffness was achieved with somewhat greater finesse. Examples include the Benjamin Franklin Bridge in Philadelphia, the bridges across the Hudson River at Bear Mountain and Poughkeepsie, the bridge across the Ohio River at Maysville, Ky., the several suspension bridges between West Virginia and Ohio, and the Waldo Hancock Bridge in Maine.

From Economy to Disaster

But then came the 1930s and the Great Depression. Bridge design engineers found themselves under the greatest imaginable pressure to economize, leading them to extend the Melan design theory to its limits. Thus many bridges built during this period—the Deer Isle Bridge in Maine, the Thousand Islands Bridge between New York and Canada, the Whitestone Bridge at New York City over the Long Island Sound,



Pioneers crossing the East River. The Brooklyn Bridge is the longest example of the unique cabling system devised by John Roebling in the 1850s. The 6,000 galvanized-steel wires were carried across the river, two at a time, by a traveling wheel. These continuous wires formed 19 skeins for each cable. The photos show cable workers and the cableway atop one tower with half of the skeins in place and an early visit of the bridge trustees venturing onto a temporary walkway used in building the cables. With cables complete came the task of suspending the platform (drawing at far right). A strap wrapped around the cable is fitted with two downward-extending ears, into which a suspender, fitted with matching ears, is to be fastened by means of a pin.

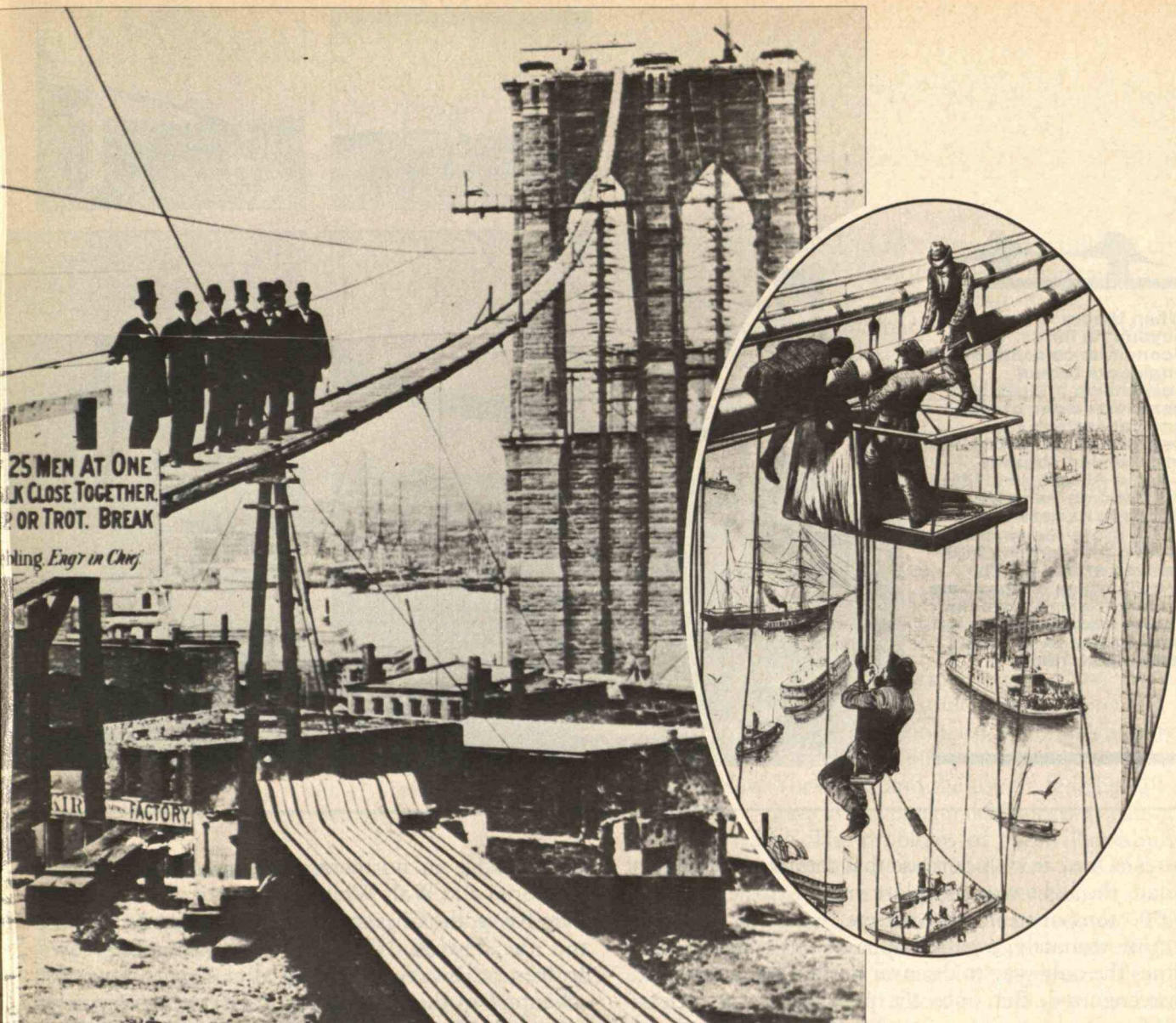


and the Tacoma Narrows Bridge at Tacoma, Wash., over an arm of Puget Sound—were designed with a relatively shallow plate girder instead of the heavier, conventional truss adjacent to the platform. The goal was to provide the minimal stiffness necessary to prevent excessive movement of the roadway under heavy loads while maximizing the economy of construction and the aesthetics of a slender, even gossamer structure.

The most extreme design in this quest for economy was the Tacoma Narrows Bridge. Even during construction, workers on this bridge noticed that the structure was undulating in the breeze, and motorists using the bridge when it was completed were often treated to the odd spectacle of seeing cars ahead disappear behind a wave in the floor. Though the engineers recognized that this was not a desirable condition, they did not recognize it as catastrophic. They therefore decided to let the bridge stand as built until

careful model studies could be completed to determine the best means of reducing the instability and deformation. However, nature chose not to wait for the perfect solution, and in November 1940 the bridge was destroyed by the harmonics induced by a broadside wind of only modest velocity—about 45 miles per hour.

The George Washington Bridge between Manhattan and New Jersey barely escaped a similar fate. It was designed in the late 1920s for ultimate service as a double-deck bridge, with ample stiffness. But only the upper deck was installed at first, with the lower deck and the main stiffening members omitted until heavier traffic should require more capacity. This strategy actually placed the bridge in a potentially precarious situation. However, it had one saving advantage: the main cables as built were adequate to support the proposed double-deck bridge. The dead weight of these cables—very heavy with respect to the



initial construction—provided adequate stiffening to prevent catastrophe.

The Thousand Islands Bridge, designed by the founder of the author's firm, David B. Steinman, was the first of these relatively unstiffened bridges. During construction, Steinman received word that the bridge was undulating in the breeze, and he immediately acted to restrain the bridge and break up the harmonics. His solution was to add stays radiating from the roadway level at the tower to the main cable in the adjacent spans. The building of Steinman's Deer Isle Bridge in Maine was at that time just beginning, and he carefully designed a system of stays of the same type to be incorporated during construction. Roebling himself used stays between tower and bridge deck for stability in all his suspension bridges. Indeed, these very visible diagonals are Roebling's trademark—evidence of his early sensitivity to a problem that eluded some of his successors for 60 years.

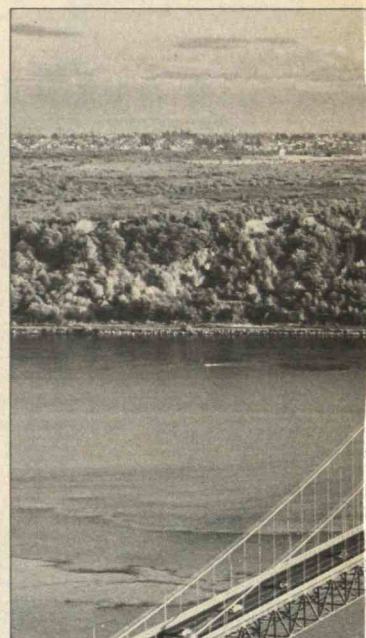
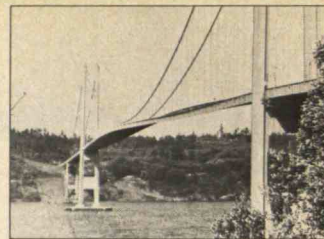
Solving the Stability Problem

Steinman's experiences, together with the Tacoma disaster, brought engineers face to face with a force of nature that until then had gone unrecognized. A perfectly horizontal broadside wind could lift the deck like an airplane wing, generating an upward force of such intensity that the stiffening members acted as little more than cloth ribbons. The engineers found they had to deal with aerodynamics and not simply the static forces applied by wind. Indeed, the Tacoma Bridge was perfectly designed, on the basis of existing criteria, to withstand a wind of up to 125 miles an hour considered as a simple horizontal force against the bridge.

Why did engineers, who were surely aware that in the previous century suspension bridges had frequently been destroyed by wind, have this blind spot that veiled the potential for trouble in their new struc-



When theory is pressed beyond its limits. To economize on costly steel, engineers turned suspension bridges into gossamer webs of wire and concrete in the Depression years. But that trend ended abruptly when a 45-mph wind lifted the Tacoma Narrows Bridge to its destruction in 1940. (Note the single plate girder forming both rail and stiffener.) The rebuilt bridge on the same towers (right) shows the "brute-force" solution—a deck stiffened by a full-length box frame.



tures? One can only surmise that they were unable to relate the light wooden platforms of earlier days to 6,000 tons of steel and concrete.

Unfortunately, a catastrophe of this type is sometimes the only way to discover natural forces hitherto unrecognized. But once the problem became clear, studies mushroomed overnight. There was never any possibility of a subsequent disaster from the same cause. The only problem was that of identifying the best and most economical methods of solution. Two schools of thought developed. One solution—a "brute-force" engineering approach—was to increase the stiffness of the deck, returning to designs that had proven resistant to whatever forces the wind might bring to bear. The other solution, based on aerodynamics, was to develop a bridge cross-section with a shape less affected by wind, so that catastrophic aerodynamic forces would not be generated.

The first school of thought is represented by countless modern bridges provided with increased resistance to both vertical and rotational movement. The "brute force" approach soon mellowed to a more sophisticated philosophy that includes adequate stiffness and a due regard for aerodynamics. Most of the designs therefore include features such as open strips in the deck floor to reduce wind lift. Examples include the second Tacoma Narrows Bridge, the Mac-

kinac Bridge in northern Michigan, the Delaware Memorial and Walt Whitman Bridges over the Delaware River, the Chesapeake Bay Bridge at Annapolis, and the Throgs Neck and Verrazano Narrows Bridges in New York. Almost all designers now take advantage of the opportunity to test their designs by means of sectional or full models in wind tunnels.

The other school of thought led to a new type of structure pioneered by the British, the first example of which was the suspension bridge over the Severn River between Bristol, England, and Wales. The suspended structure, comparatively shallow in depth, has a cross-section like the streamlined hull of a ship that discourages the generation of vertical aerodynamic forces, assuring freedom from catastrophic lift.

Still more recently, the stability problem in long-span bridges has been solved by the so-called stayed-girder design. This has the roadway and towers of a suspension bridge, but the cables are straight stays from the top of the tower to various points on the roadway. There are no massive flexible suspension cables in which harmonics can develop. This type of bridge has been found to be competitive in cost with conventional suspension bridges for spans of up to about 1,500 feet, the length of the Brooklyn Bridge.



The Gerontology of Bridges

Despite its remarkable design that makes it a crown jewel among bridges, the Brooklyn Bridge is not immune to danger as it enters its second century of service. Like most other bridges supported by public funds, it suffers from lack of proper maintenance.

The Brooklyn Bridge and its three younger sisters—the Manhattan, Williamsburg, and Queensboro Bridges, which form the four major overhead crossings of the East River between Manhattan and Brooklyn or Queens—serve as a good sample of the nationwide problem. Though some national funds are available for bridge maintenance, the program is by no means adequate to do all the work that is needed. State and local authorities establish priorities and assign available funds accordingly. These four bridges have found their place in the priority, and inspection, rating, and rehabilitation have been in progress since 1978.

Some \$30 million is to be spent in 1983 on the Brooklyn and Queensboro Bridges, and at least \$100 million of work will have to be done in the next several years on each of the four East River spans. Although this is a major investment, it is far less than the cost of rebuilding any of these bridges, if only because of the disruption of traffic and property dur-

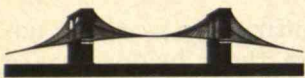
ing reconstruction. And reconstruction would be unthinkable to many because these bridges are a cherished part of the metropolitan scene in New York. Indeed, the Landmarks and Art Commissions do not want to see a single change in outline.

Each of these bridges has special characteristics and needs. The Queensboro Bridge is a large truss bridge of the cantilever type spanning just under 1,200 feet, which now carries eleven lanes of vehicular traffic. The Williamsburg Bridge is a 1,600-foot suspension bridge carrying eight lanes of vehicular traffic and two lanes of rail traffic. The Manhattan Bridge is a suspension bridge with a 1,470-foot main span that carries seven lanes of vehicular traffic and four lanes of rail traffic, while the Brooklyn Bridge carries six lanes of traffic (limited because of the original design to passenger cars and light vans) and a 12-foot elevated pedestrian and cycle promenade.

Most of the deterioration on the Queensboro Bridge is simple corrosion due to the savage environment of New York City and the use of de-icing salts. In addition, there is pavement deterioration caused by heavy traffic. The problems of the Williamsburg Bridge are similar but in addition there is a special problem. Unlike those of most suspension bridges, the main cables were made of ungalvanized wire. The deterioration is not nearly as extensive as one might expect after 80 years of service, but engineers will still have to do a great deal of soul-searching to find the proper way to prevent further corrosion among the cable wires.

In addition to all the problems of the Queensboro Bridge, the Manhattan Bridge (its cables are of galvanized wire) has two special problems of its own. In the first place, rail traffic has had a devastating effect on this bridge. The four tracks are located at the sides of the bridge, one pair at each edge. Whenever a train crosses the main span, there is torsional stress and movement of the structure. When two trains travel in parallel, the forces are greater; and when trains travel simultaneously on all four tracks, the forces are very large indeed. The second problem, which compounds the first, is that the suspended structure is attached to the cables in a way that makes it very difficult to determine the dead load stresses in the structure.

The design of the Brooklyn Bridge also makes it difficult to determine the distribution of dead load to the four cables. Another problem is inherent in the atypical features of this design: the short suspenders at midspan swing by several degrees away from the



The new and the old. When engineer David Steinman learned that the platform of the Thousand Islands Bridge was moving in the wind, he added diagonal stays such as those on his later Deer Isle Bridge in Maine (left). The Verrazano Narrows Bridge is stiffened by under-platform girders. But the Brooklyn Bridge (right) remains "the most cherished and admired work of civil engineering in the Western Hemisphere," says the American Society of Civil Engineers.



vertical in response to extremes of temperature. The bottoms of the suspenders move toward midspan in summer and toward the towers in winter. The suspenders have never been properly attached to the cables to allow movement of this type, and new materials and details are now being considered to provide a better solution.

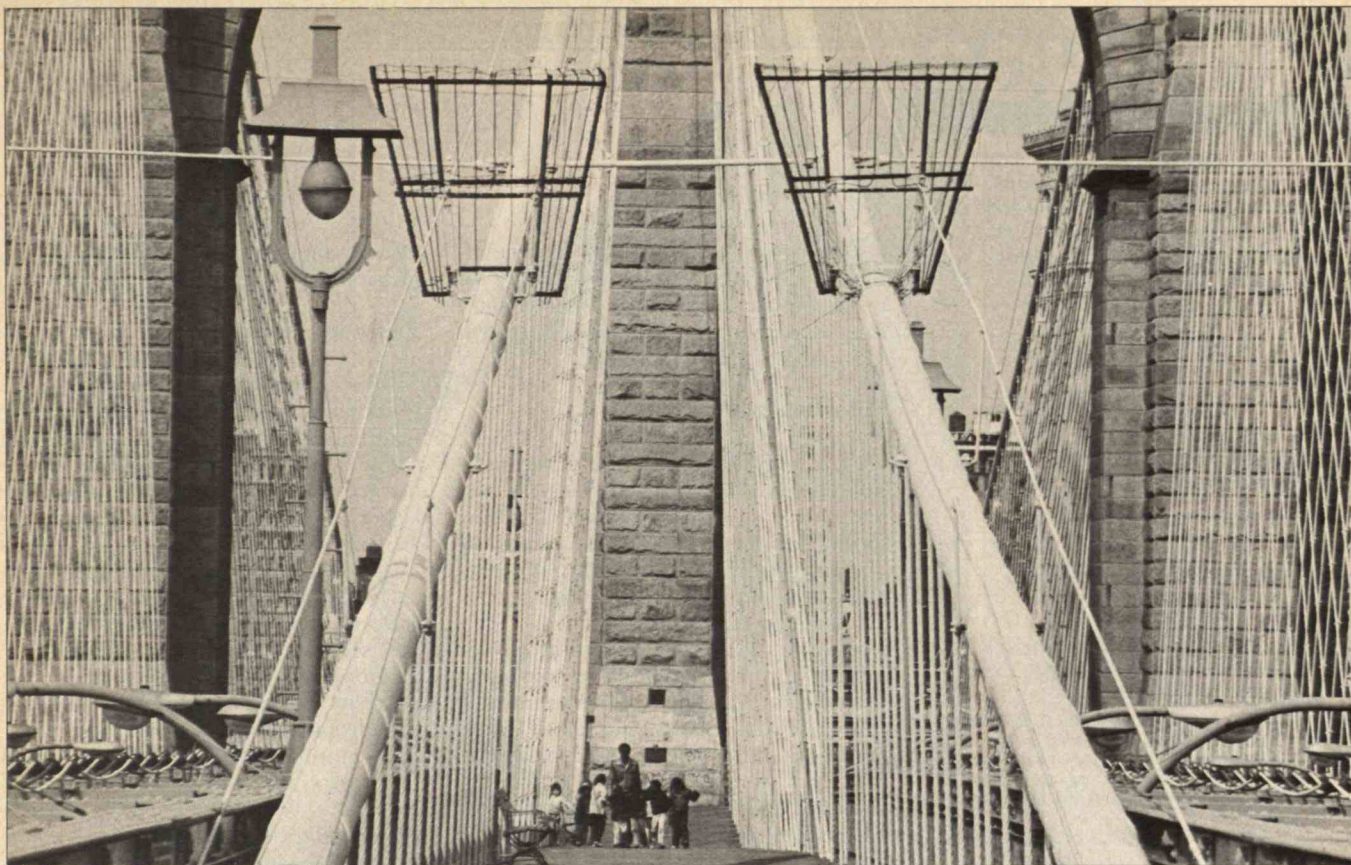
Beyond these difficulties, the main problems are those caused by the environment. Corrosion is especially concentrated in the main cable anchorages and the anchorages of the diagonal stays at the tops of the towers. In the anchorages, where the cables are held to the bridge foundations, many broken wires will have to be repaired, and some bundles of wires may have to be cut off where they emerge from the main cable and tied back to the anchor heads with new material. The problem is that the anchor chambers are not waterproof; this will have to be corrected, and perhaps the chambers provided with controlled atmosphere, to arrest corrosion in the future. At the tops of the towers, all of the diagonals that pass through the tower top will have to be reanchored and made more accessible for maintenance.

Moisture is, of course, a principal culprit in all this deterioration, especially when it appears in the presence of salt used for de-icing. Indeed, the greatest boon in this field would be to find a de-icing material other than salt, for it is the greatest corrosion-producing agent in the environment.

In the design of new structures, every detail is now reviewed specifically with corrosion protection in mind. Some designers use corrosion-resistant steel, but this must be used with care because it is not panacea. Expansion joints along the roadway have been a frequent cause of trouble, for it is very difficult to prevent moisture from passing through these joints to the steel below. However, joints are being developed that promise to go a long way in this direction. It is currently normal practice to study drainage problems carefully so that moisture will be carried off and away from the structure as quickly as possible. Concrete typically used for the platform slab is not impervious to moisture, so engineers require a bed of special sealing membrane over the concrete before applying a final roadway surface of asphalt. Alternatively, several concrete additives are in experimental use to reduce the permeability of the upper layer of the concrete slab.

Ending the Neglect of Public Bridges

These problems are not the fault of the people responsible for maintaining our bridges. On the contrary. That these four bridges—and many others throughout the country—are still viable for transportation is a great tribute to the skill and dedication of their original builders and of those charged with their maintenance through the years. The problem is that



money has often been unavailable for regular preventive maintenance. Indeed, in the competition for funding, bridge maintenance has been pitted in a lopsided contest against many other more visible public needs. Bridge maintenance has too often been operated like a fire department—rush to the scene of a problem when one appears.

Public awareness of this problem was finally sparked by the disastrous failure owing to corrosion of the suspension bridge over the Ohio River at Point Pleasant, W. Va., at the end of 1967, in which 46 lives were lost. Extensive publicity resulted from the inspection of deteriorated bridges mandated by legislation after the West Virginia disaster, modest funds have now been made available, and some of the bridges are finally receiving the attention they need.

There is hope that bridge maintenance can be accelerated as a result of the recently enacted gasoline surtax. But even these additional funds are likely to be inadequate, and public understanding must be increased. In short, we must find some way to avoid repeating the cycle of deterioration and crash repairs.

The neglect of public bridges is in marked contrast to the careful maintenance generally accorded toll-supported bridges, which generate their own funds for maintenance. Those responsible for upkeep are able to both plan and carry out preventive maintenance programs. The result is that, in general, our toll bridges are in excellent condition.

In today's economic climate it would not be politically possible to place tolls on bridges that have been free for many years. But here is a modest proposal to encourage public understanding of the fact that "free" bridges are not really free.

For any bridge, it is possible to budget preventive maintenance for a two-year period with considerable certainty and for five years reasonably well. Given accurate traffic predictions, one can determine, approximately, the amount of maintenance money associated with each anticipated vehicular crossing. A display system could readily exhibit to drivers crossing the bridge the growing maintenance liability—typically several cents per crossing—that their use of the bridge entails. This would be a graphic way of keeping the public continually aware of a problem that is too easily neglected.

Indeed, it would be more than fitting if celebration of the first century of service of the Brooklyn Bridge could become the catalyst for wide and increasing public commitment to the rehabilitation and maintenance of our great bridges, returning them to, and then retaining them in, the condition in which they were left by their designers and constructors.

BLAIR BIRDSALL is a partner in Steinman Boynton Gronquist and Birdsall of New York, of which he was managing partner from 1975 to 1982. He studied civil engineering at Princeton University and was associated with the Roebling Company for 30 years before joining his present firm in 1965.

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Cloning can be seen as an extreme effort to impose a particular identity—a particular character—upon a descendant. But all human genetic engineering will move us toward that extreme.

Genetic Lottery

Genetic engineering is the ultimate technology, for it makes plastic the very user and creator of that technology. This new tool makes conceivable a vast number of alternative evolutionary paths. We may even be able to adapt humankind to varied technological regimes.

Will we try, for instance, to breed—or mutate—people fit to work in special environments? Miniature people to travel in space or live on our overpopulated Earth? Will we create people resistant to carcinogens, radiation, and pesticides to work in chemical factories, nuclear plants, and farms? Or, alternatively, will we breed people who are better able to tolerate cytotoxic drugs should they contract cancer? What intellectual abilities, psychological strengths and life-spans would we choose?

I hope it is clear that the whole character of human life is at issue. To use a simile: Life has been a game, like cards, where each of us seeks to make the best of the hands (or genes) dealt to us. Shall it become a game like football, a collective strategy in which people play assigned roles in a coordinated plan? Or might it become more like a card game with a rigged deck, with more aces and fewer treys. If so, who designates the aces?

How will people react when they realize that their very genes are the product of a social decision? Will they rebel against such predestination? Will they become sullen and passive? Or will our descendants be proud they were each "planned," not the product of a genetic lottery but the recipient of the best inheritance our culture could devise at the time? How will they then react should a better model become available during their teens?

To what extent should we consciously leave a place for the element of chance in human affairs?

I suspect there is no turning back from the use of this awesome knowledge. Given the nature of our society, which embraces and applies any new technology, it appears that there is no means, short of unwanted catastrophe, to prevent the development of genetic engineering. It will proceed. But this time, perhaps we can

seek to anticipate and guide its consequences.

Taking the Larger View

I believe the university is the place to address and analyze the social consequences of technological innovation. Yet even in academia, pressures for immediate results distract researchers from the quest for deeper understanding. Indeed, a salient characteristic of our increasingly secular society is its emphasis on the short-term payoff. We must try to avoid this myopia in developing this new technology. We must seek to protect the larger view.

Among other things, we must insist that university research continue to be available for public scrutiny in the open scientific literature, that it not be secreted as proprietary information and industrial know-how. We must also insist that private funding directed toward patentable and profitable inventions does not grossly exceed public funding directed toward the general increase of knowledge, including an understanding of possible hazards.

I would suggest that what we sorely need now is a new group of trained professionals to mediate between scientists and engineers on the one hand and citizenry on the other. Such professionals should be practicing scientists more broadly educated in our humanistic traditions. They would be trained to understand the potential implicit in this new technology, able to balance the ethos of environmentalists with the concerns of those who cherish civil liberty, able to perceive the imperatives of a technological society and still bear in mind that technology exists to serve. They would remember that the human species is very diverse, that it encompasses both a Mahatma Gandhi and an Adolf Hitler.

Ecclesiastes, tells us that "he that increaseth knowledge increaseth sorrow." The modern version might be "he that increaseth knowledge increaseth power." Western society has become, in a sense, an extraordinary machine for converting knowledge into power.

Human beings, of course, are sprung from the same DNA and built of the same molecules as all other living things. But if we begin to regard ourselves as just another crop to be engineered, just another breed to be perfected, we will lose our awe of humanity and undermine all sense of human dignity. □

Solar House

(Continued from p. 56)

consumption if I assumed infiltration of one-half an air change per hour, instead of the one-third considered conservative for a well-built, superinsulated house. Why the difference?

I finally traced the problem to four small air-to-air heat exchangers installed on the east and west sides of the house. These heat exchangers remove possibly harmful stale air from a tight house without the opening of windows. Stale air is blown out through one set of small tubes while fresh air is sucked in through another set. These sets of tubes are intertwined so that heat from the exhaust air may transfer to the incoming fresh air. This device is about 70 percent efficient, and each exchanger was supposed to change about one-sixth of the air per hour. But when the prevailing westerly winds blew, a breeze could be felt throughout the house—ample evidence of far larger infiltration. Although the tenants used blankets to cover the two heat exchangers on the west side, I believe that even this measure failed to reduce air infiltration to the anticipated rate.

A Vote for Solar

To evaluate the economic viability of my superinsulated passive-solar house, I analyzed the pros and cons of each feature.

I could not justify including a sunspace solely because of its heat contributions. The cost of the sunspace was about \$10,000, roughly 10 percent of the total house cost. Its contribution of solar heat to the rest of the house was a few million Btus—perhaps \$50 worth of electric heat per year. On the other



hand, the sunspace does enhance the aesthetic appeal and quality of life in the house. Residents can grow hardy plants and flowers—even vegetables—and enjoy the luxury of eating, working, and reading surrounded by the sun's warmth during the coldest winter weather.

Triple-glazed windows are well worth the cost. An investment of \$3 per square foot saved 4 Btus per degree day per square foot. This is equivalent to 65 cents of electric heat per square foot, yielding a payback period of under five years.

If the sliding shutters are closed 14 hours a day, they save 4.5 Btus per degree-day per square foot, or 73 cents per square foot a year. Since the cost to fabricate these, form the pockets to receive them, acquire and install the necessary hardware, and paint them came to \$13 per square foot, their economic value is dubious. But the tenants reported that they improved personal comfort. In comparison, adding insulating curtains, which cost about \$4 a square foot and provide a thermal resistance of R-2, would save 40 cents

per square foot per year on a triple-glazed window. I recommend that the choice of window insulation be left to the owners.

The double wall with its extra insulation yielded heat savings over a conventional two-by-four-studded wall of 8,900,000 Btus per year, or \$223 worth of electricity. Since the added wall and insulation cost approximately \$1,500, this was a worthwhile addition.

The cost of the 6-inch concrete slab under the south part of the house was \$350 more than the cost of a 4-inch slab, with an added expense of \$500 for the underlay of styrofoam. If we assume that this mass retains at least 40 percent of the incoming solar heat, this means saving an extra 3,200,000 Btus per year, or \$80 worth of electricity—justifying the added expense over time. However, the dark slate flooring in the living room and entry hall, which costs \$4 per square foot more than vinyl flooring, cannot be justified except on esthetic grounds. The den floor (also with southern exposure) has a thin vinyl flooring over the 6-inch concrete,

and residents could not detect a temperature difference between the living room and the den after a sunny day.

First-year results with the solar-powered domestic hot-water system were also very good. The water is heated by 90 square feet of collector panels and stored in a 300-gallon hot-water tank. As backup, a 60-gallon electric hot water heater is separately metered.

Hot-water consumption during the year averaged 65 gallons per day. Heating that much water without solar assistance would have required about 15 kilowatt-hours of electricity per day—a total of about 5,500 kilowatt-hours per year. The actual electricity consumption for heating water for the year was 1,151 kilowatt-hours. This means that the solar system contributed 79 percent of the hot-water heat, a savings of \$315 in one year. Since the installed system cost \$4,000, reduced to \$1,560 through federal and state tax deductions, it should pay for itself in five years.

An overall comparison of my house with that of a comparably sized conventional house suggests that many of its special features are worthwhile. A rule-of-thumb price for a house like mine, but without the special insulation or solar features, would be \$56 per square foot, or a total cost of about \$84,000. My own house cost \$90,000, but the extra \$6,000 generated fuel savings of \$1,250 a year. Given such savings, the solar and superinsulating features of the house should pay for themselves within five years. I consider that a sound return on the investment.

MARK HYMAN, JR., is president of Solar Heat Corp. in Cambridge, Mass.

Cable TV: Competing in the Wrong Place

The overbearing mother gave her married son two ties for his birthday. And ever anxious to please, he put one on when next she visited. But to no avail. "What's the matter?" she asked. "You didn't like the other one?"

In a similar way, the promise of cable—its "television of abundance"—is beginning to sour. Its problems derive from the fact that one person can watch only one program at a time.

Overall, cable is still as vital as ever. Some 29 million homes now receive it, and the number is growing by 300,000 each month. But even though viewers may be buying more, the providers are enjoying it less.

A recent survey by the A.C. Nielson Co. showed that when viewers had an average of only 3.6 channels to choose from, they watched 72 percent of them for at least 10 minutes each week. But when 12.4 channels were available, the rate went down to 50 percent, and when the number of channels rose to 29, the relative viewing dropped even further—to 34 percent. The percentage of all available channels that subscribers viewed went down (even though the actual numbers—2.6, 6.2, and 10, respectively—went up) because the total audience did not automatically enlarge itself to meet increased offerings, much to the producers' chagrin.

A comparable phenome-

non is the fading of "multiple-pay"—subscriptions to several pay services such as Home Box Office and the Movie Channel at the same time. According to the *Wall Street Journal*, this profitable enterprise "is losing some of its sizzle. . . . Companies are conceding that the concept of selling three or more pay services isn't working as anticipated."

The difficulties of both multiple-pay and numerous cable channels may lie not so much in the quantity of choices as in their quality. Providers of packaged, polished, and expensive cable programming for mass audiences bemoan viewer response, but in general they offer little that conventional broadcast networks do not already present for free. And the large-scale advertising that might offset the high cost of production for these special offerings continues to go to the established networks.

What many producers seem to have forgotten is that the main appeal of cable does not lie in mass programming—where it must compete with the broadcast networks—but in its "narrowcasting" capability. Cable can deliver specialized programs to specific audiences and attract advertisers whose messages are customized accordingly.

If the trend toward echoing the broadcast networks derives from overcentralization—where a single company controls all the cable programming offered to a community, and that company is in turn part of a larger conglomerate with its own programs and ideologies to sell—then some changes may be in sight. In October, the Mountain States Legal Foundation (a Denver-based public-interest group) filed a

lawsuit that challenged the city's right to grant a franchise to a single company. The foundation maintained that such a franchise—a "de facto monopoly" on disseminating information—violates the First Amendment and inhibits competition that would provide the public with the best possible service and the greatest variety of choices. The case has not yet been tried, but many observers in the cable industry predict it will eventually go to the Supreme Court.

Sole franchises, such as the one the Denver suit is challenging, do in fact provide some of the narrowcasting that seems right for cable—public-access channels—but only under pressure by the community. According to a recent article in *Channels* magazine, "Community-access enthusiasts want to set aside for the free, relatively unrestricted use of the public a few lanes on the new superhighways of telecommunications."

That is what cable companies often promise during the fierce competition for a franchise. Unfortunately, the reality of such community-oriented narrowcasting does not always materialize. "What worries me," says Sue Miller Buske, executive director of the National Federation of Local Cable Programmers, "is what happens after the franchise is granted."—S.J.M. □



Giving Robots Touch

Take a small square circuit board etched with tiny parallel wires, a small square of silicon rubber imbedded with tiny parallel conductors, and a piece of nylon stocking (L'Eggs, Extra Sheer). Make a sandwich of these three, laying the circuit board and silicon so their conductors are cross-wise to each other—like a checkerboard—with the nylon in between. Then connect each of the conductors into an oscilloscope, a video tube that records whether current is present or absent.

What you have made is a primitive solution to one of the cantankerous problems of robotics: how to give a machine a sense of touch. To use this simple device, press a small washer against it and put a low voltage into each wire of the circuit board, one at a time. The resulting flow of electricity among the conductors defines the different points of pressure, so the oscilloscope reveals the shape of the washer.

Without such sensory input, says John Hollerbach of the M.I.T. Artificial Intelligence (AI) Laboratory, a robot has the same problem as a human who attempts to manipulate objects with numb fingers. It has no sense of grasp nor any feeling of the shape and position of whatever it's holding.

The checkerboard-sandwich approach was conceived by Daniel Hillis, a graduate student in the M.I.T. AI Lab. Hillis has mounted a more sophisticated version of the touch

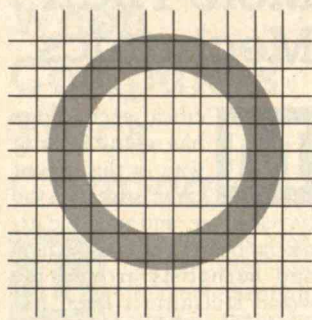
sensor on the curved tip of a mechanical finger. This finger, which moves much as a human finger moves, senses the shape of the unknown object, then rotates it to sense how easily it rolls in different directions and to detect bumps and depressions. The finger relies on a built-in computer (not an oscilloscope) to convert electrical information collected by its sensor into digital data. By comparing this information with programmed data, the computer can distinguish among six common pieces of hardware—a machine screw, dowel pin, cotter pin, set screw, lock washer, and flat washer. Hillis believes his device is a significant first step toward devising the mechanical hand of the future.

The next stage—designing a mechanical finger that can recognize a large variety of parts—will be much harder. One part of that task is already being tackled at Carnegie Mellon University, where Mark Raibert of the Computer Science Department is substituting silicon

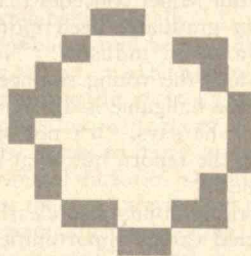
chips for the crossing points of the wires on Hillis' sensor. The robot can then receive larger images that are "preanalyzed." Even tougher will be the ability to recognize texture (the difference between paper and glass, for example), measure thermal conductivity, and construct a picture of an object larger than the area of the sensor. The finger would do this by moving its sensor across the object and gradually assembling a picture of the whole like a jig-saw puzzle.

Though these tasks are deceptively simple for humans, a robot that could do them would be nothing short of a "miracle," says Patrick H. Winston, director of the M.I.T. AI Laboratory. But Winston is confident that robots can eventually be as adept as the rest of us at choosing and using hardware—among many other tasks.

"I don't see any reason why a lump of silicon can't be just as smart as a lump of neural tissue," Winston says.—J.M. □

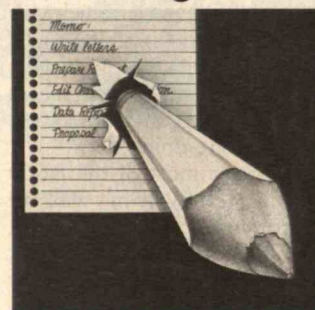


Squeeze an ordinary washer against a sandwich of red and blue conductors separated by a nylon stocking. Electric current will flow between the conductors only where the washer presses on them, and presto—a com-



puter programmed to "read" the resulting current creates a digital image of the washer. A computer-controlled finger based on this principle can now distinguish among six common pieces of hardware.

Engineer's Invisible Activity: Writing



Scientists and engineers rarely think of writing as a major part of their professions. Yet a study of writing in a corporate research and development group has shown that technical professionals typically spend over a third of their work week writing, editing, or preparing oral reports. Thus, the investigators believe that university programs aimed at sharpening writing may boost productivity in industry.

James Paradis and David Dobrin, professors in the Technical Communication Group in the Department of Humanities at M.I.T., studied a group of 25 staff engineers and scientists, 6 supervisors, and 2 managers at the Intermediate Technology Division of the Exxon Chemical Co. in Baton Rouge. The group's daily routine included writing letters, data reports, memos, proposals, and formal reports, as well as making oral presentations. Both the staff engineers and the managers spent over 30 percent of their time writing or editing, while the intermediate supervisors spent

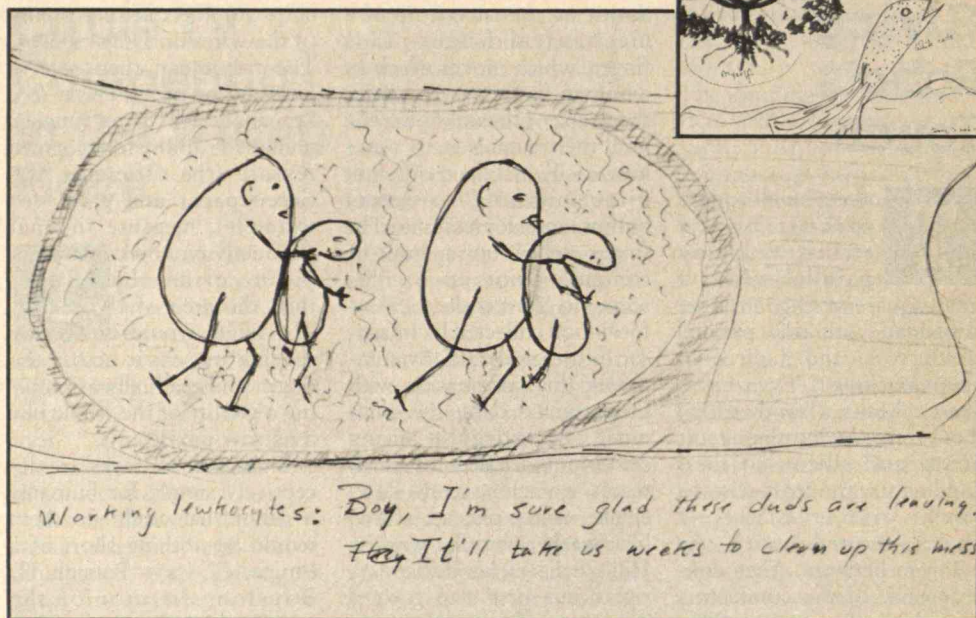
over 40 percent of their time at these tasks. All three groups spent an additional 5 percent of their time preparing oral presentations.

"We were surprised by the M.I.T. people's results—especially about the supervisors," admits Richard Miller, leader of the technical research group. "The managers were reading, the engineers were writing, and the supervisors were doing both."

Though most of the R&D group felt writing was an "unproductive" activity, Paradis and Dobrin found, it nevertheless served subtle yet crucial purposes. Writing was vital in decision making, because it set complex concepts into a form allowing others to evaluate and respond to them. Writing was an important way for management and staff to coordinate their activities. And exchanging ideas through writing often stimulated new avenues of thought.

But writing was a hidden activity that few people talked about—as Miller says, it "somehow just got done." This lack of communication about the writing process caused tension. For example, supervisors and managers edited technical papers to make them more useful in accomplishing the company's overall objectives. However, since most of the scientists and engineers intended their papers as detailed descriptions of their work, and assumed that the purpose of the editing was merely to eliminate factual or grammatical flaws, they often mistakenly saw supervisors' corrections as arbitrary and subjective.

Miller blames such misunderstandings in part on universities, which typically evaluate details rather than the overall import of what students do. Significantly,



Patients' drawings reveal their unconscious beliefs about their disease, treatment, and body's defense mechanisms, enabling doctors to treat the patients more effectively. A Quaker, told he would be given treatment that

would "kill" his cancer, unconsciously rejected the idea of killing and could not be helped. Above: He later responded to the notion of "curing" his illness by thinking of his white cells as carrying away the cancer cells.

Inset: A woman envisions her treatment as containing cancer cells in a box. She sees her defense (white cells) as eating the cancer cells, and pictures herself as a vibrant sun. Her chances of recovery are good.

over half the group felt that either job experience or company courses had offered the most useful training in writing. But Miller concedes that recent graduates need more guidance in industry. "No one tells the young engineer that the ballgame is different here," he says. "It's not so much the report, but what it all means."

Writing ability also clearly affected career opportunities at Exxon. Both the managers, all 6 of the supervisors, and 10 of the 25 staff members could recall situations in which writing influenced a researcher's chance for advancement. If any doubt remained, Paradis and Dobrin's work underlines the importance of writing in a society based on information.—

David R. Lampe □

Medicine: More Than Mechanics

Medical technology has come a long way in this age of laser surgery, the CAT scanner, and now the artificial heart. Yet faith healers and herbalists around the world still attract large followings, and in the United States, disillusionment with the limitations and cost of conventional medicine has produced widespread interest in the holistic health movement. At its best, holistic health treats the whole person—mind and body—as an inseparable unit.

"I was trained to be a

mechanic and a lifesaver," Dr. Bernard S. Siegel, a surgeon who teaches at Yale School of Medicine, told an audience of 1,200 attending the annual holistic medicine conference sponsored by Interface Foundation in Boston last winter. But being a mechanic wasn't enough.

When patients think positively about their treatment and take active roles in curing a disease, the progress is impressive, says Siegel. Unfortunately, the opposite is also true. If patients think of chemotherapy as poison, for example, their bodies respond as if being poisoned.

To help patients deal holistically with illness, Siegel established Exceptional Cancer Patients, Inc., in New Haven, Conn. Support groups for patients and fami-

lies meet weekly to discuss how to gain control of their lives, resolve conflicts, and strengthen positive attitudes. The groups learn relaxation and meditation techniques, and patients visualize medical therapy as helping, not overpowering, the body to eliminate the disease. They draw pictures of themselves and their disease to discover subconscious feelings and thus gain a more productive attitude toward their treatment.

For example, a patient who envisions radiation treatment as a golden beam of energy is likely to have less redness, less tissue breakdown, and less pain than a patient who pictures the treatment as an enormous monster, says Siegel. Likewise, a patient who depicts cancer cells as slugs or snail-like creatures has a better chance of combating the illness than one who sees cancer as crabs (which hold on), according to studies by psychologists Jeanne Achterberg of the University of Texas Health Science Center in Dallas and G. Frank Lawlis of North Texas State University. When patients see the cancer as a formidable foe, they may be saying they are less able to put up a fight.

"I can tell when patients have residual cancer—even before they know it and before tests show it—by looking at their pictures," says Siegel.

Because the term "holistic" is vague, Dr. Herbert Benson, author of *The Relaxation Response* and *The Mind/Body Effect*, prefers to discuss his work in more concrete terms. A cardiologist at Beth Israel Hospital in Boston, he has successfully treated a number of disorders, including hypertension and heart irregularities, using customary medicine along with "the relaxation response" induced

by meditation techniques.

"Certain thought patterns evoke chemical changes in the body, such as when stress increases adrenaline secretion," he says. "Stress may make some diseases worse and may actually cause others. We counteract the harmful effects of stress by producing the opposite response, the relaxation response."

Some cancer patients are also using the relaxation response in a program directed by Dr. Joan Z. Borysenko at Beth Israel. But doctors don't yet know whether this works in treating cancer, Benson says.

According to Dr. Emil Frei III, director and physician-in-chief of the Sidney Farber Cancer Institute in Boston, "Whether motivation does something directly to the body that adversely affects a tumor is still something that nobody knows for sure." But he agrees that patients who are well informed, well supported by their primary physicians, and highly motivated to get well do better than those who are not.—S.K. □

When Computers Track Criminals

Law enforcers keep "tabs" on law breakers through criminal histories, and for the past couple of decades computers have aided those efforts. Now a report released by the Congressional Office of Technology Assessment (OTA) warns that while law officers are keeping more tabs than ever, they are not necessarily better.

Written at the request of



House and Senate judiciary subcommittees to examine a planned national computerized criminal history (CCH) system, the OTA report expresses the fear that too many people already have easy access to too much inaccurate information.

The system now used by the FBI and thousands of other federal, state, and local law-enforcement agencies serves as an electronic catalog of criminals at large and stolen property. In addition, millions of criminal histories are logged into the computer banks of CCH systems in 27 states. And the FBI's non-computerized Ident system makes about 6 million arrest records and fingerprints available nationally.

What would be the advantage of maintaining a nationwide CCH system? Some law enforcers argue that access to more complete criminal histories would assist them in carrying out procedures such as booking, pre-trial release, and bail. According to one study described in the OTA report, local tests show that the proposed national CCH system could reduce Ident's processing time for fingerprint checks, now carried out by mail, from about 36 workdays to three hours.

However, other law officials have doubts about

whether the new system will be worthwhile. Kenneth Laudon, a professor of computer applications at New York University and a researcher for the OTA report, says that local police, judges, and prosecutors don't trust even the existing statewide CCH systems.

He told *Privacy Journal* that "local law-enforcement people don't think a national system is worth paying for out of local funds. Ninety percent of serious crime is committed by offenders in the neighborhood. Police know who is committing the crimes. The national system doesn't help them on this. Multistate offenders are not a prime priority for local police."

Whether or not a new national CCH is needed, the OTA recommends removing the bugs from the current tracking systems. According to the report, nearly one-third of the information transmitted electronically to state police is incomplete. A 1979 study cited by the OTA found that only 70 percent of the FBI's Ident records contained information on the disposition of a case—whether charges were dropped before trial and whether suspects were found innocent or guilty. Because one-third of all cases are dismissed before trial, such incomplete records

can hurt innocent people. In addition, the OTA report found that about one-fifth of the Ident records were inaccurate.

As *Privacy Journal* reported, the gaps and inaccuracies were "particularly troublesome in view of the OTA report's finding that these Computerized Criminal Histories are widely disseminated to state licensing boards, employers, and security investigators."

As of fiscal year 1981, the OTA study showed, over half of the requests to the FBI's Ident system came from such non-criminal-justice users. Attorney Neal Miller, who studied this issue for the Labor Department, concluded that "a preponderance of large employers seek criminal-record information." According to an article in the *New York Times Magazine*, employers regard any record of arrest as "a powerful mark against the applicant."

Jeffrey Meldman, a member of the OTA's Computerized Criminal History Systems Advisory Board and a professor of management science at M.I.T., shares the concern about computerizing criminal histories. "Once you send out information like that," says Meldman, "it's very hard to control. That could be harmful. Employers could have a policy of not hiring anyone with a criminal record—which is discriminatory. Extortion is a possibility, and just embarrassing people is another. All these things are exacerbated by the inaccuracies and incompleteness of the information."

The OTA recommended legislation to avert such abuses. Yet how to frame such laws remains a question.—Art Jahnke □



Holography: A Technology in Search of an Application

Holograms—three-dimensional pictures embedded in thin pieces of plastic or projected onto air—show how objects look from almost any vantage point. Light is scattered off of microscopic parallel lines so that at different angles, the light waves either cancel each other out or reinforce each other, creating different images.

Holograms have a trait that has endeared them to innovative thinkers. If you damage a spot on an ordinary photograph, you lose whatever information was there. But losing a section of a hologram merely reduces its overall clarity or restricts the field of view—how far around the back of the object you can look. You can even make a hologram of an apple in such a way that if you cut it in half, you don't get two halves of the apple: you get two complete apples.

The invention of holograms in 1948 inspired hopes that they would store data in pictorial form compactly and redundantly for performing complex computing tasks. These possibilities attracted research funds as the military establishments of France, the Soviet Union, and the United States raced to develop devices such as special computers incorporating holograms to analyze reconnaissance photographs.

But none of that research has panned out. "Holograms are not the world salvation people thought they would be," concludes James D. Wynne, manager of the quantum physics and chemistry division at IBM's Thomas J. Watson Research Center. "The most significant contribution they have made is in eyeglasses with open eyes hologrammed on the lenses," he says in a deadpan voice. "Really, it's the perfect solution to a problem that has

plagued scientists for years: how do you keep awake during boring presentations at technical conferences? Those eyeglasses are a great innovation. You can sleep without anyone noticing."

Such off-the-wall applications of holograms seemed to dominate the annual meeting of the Optical Society of America last October. When they weren't attending talks on such topics as "Transient Wave Analysis of Degenerate Four-Wave Mixing," optical scientists descended to the exhibition hall to buy holograms of fairies, dragons, and pyramids. The hottest item, selling out in the second day of the conference, was—you guessed it—spectacles with eyes hologrammed on the lenses, courtesy of International Dichromate.

A conventioneer from the National Bureau of Standards recounted how one year some shadowy visitors set up an exhibit of pornographic

holograms, absconding only moments before the cops arrived. Richard Rallison, senior scientist for International Dichromate, verified that those hit-and-run exhibitors had approached his company with a contract to manufacture the holograms. He turned them down.

"Until recently, holography has been a technology in search of an application," observes Tony Hsu, marketing manager of Newport Corp., a manufacturer of scientific equipment for hologram and laser research. However, his company has developed a computerized system to produce moving holograms that help engineers analyze structural stress. The hologram in effect draws contour lines over the surface of the test object. By observing the movements of these contour lines, engineers can spot areas of high stress and vibration. "They've already used this technique to spot the part of a diesel engine where knocking was occurring," reports Hsu.

International Dichromate has a contract to supply holograms for the IBM 3687 Supermarket Scanner, which uses a laser beam to read the bar codes on groceries. The holograms take the place of a complex multifaceted mirror that would otherwise be needed to direct the laser beam to the code and collect the reflections for computer processing. This and other practical applications now account for about one-fourth of the company's income, with sales to religious cults, science-fiction enthusiasts, and rock-star fan clubs accounting for the rest.

Even though holograms have finally begun moving into the staid industrial marketplace, it was clear at the Optical Society of America

conference that frivolous uses still dominate the field. "Beware of strangers in bars carrying holograms," advised one inebriated convention goer, brandishing an iridescent, computer-generated hologram of the initials "U.S.A." Other scientists concurred that a briefcase full of alluring holograms represents a major technological advance over the line "haven't I met you somewhere before?"—Carolyn Meinel □

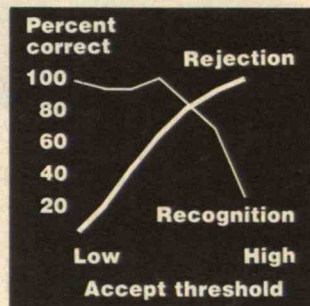
They Talk; How Soon Will They Listen?

The computer in your new car can now talk to you, but when will you be able to talk to it?

Not for a long time, says Thomas Edman of Honeywell.

The goal of communicating with computers by voice is appealing, but there is more to it than that, says Professor Michael L. Dertouzos, director of M.I.T.'s Laboratory for Computer Science. Machine cognition of speech is a major goal of Japan's \$1 billion fifth-generation computer program, he says, and "whoever breaks the log-jam to make machines that can understand spoken words will gain control over the information revolution."

The reasons are simple. Vocal communication is fast—conversation flows at 150 words a minute, twice as fast as most typists. Voice would be an ideal way to communicate with a computer for those whose eyes and hands are occupied



The trouble with today's word-recognition computers is that their margin of error is still very large. The more erroneous commands the computer is programmed to reject, the fewer correct commands it will accept.

elsewhere, such as aircraft pilots and automobile drivers. And voice could provide a third dimension of communication, supplementing today's keyboards and light pens as a way of adding still more data for a computer to work on.

But the problems are large. Although most of us use only 3,000 to 8,000 words frequently when speaking, these are selected from a vocabulary of at least 100,000 words, most of which we use at least occasionally. When we speak, we tend to run words together into what amounts to megawords. Furthermore, speech is highly individual; the fact that you can recognize a friend's voice in the dark is fine for you but bad news for a computer.

If this complex pattern of speech is superimposed on a background of noise, the computer's problem is multiplied manifold.

In principle, speech recognition is simple enough. The computer converts whatever it hears into a pattern of frequencies and then compares this pattern with a vocabulary in its memory. Their makers claim that speech-

recognition devices now on the market have vocabularies of 60 to 160 words—if those words are spoken carefully, by a voice with which the computer is familiar, and at a rate of no more than 60 to 75 words a minute. Given these conditions, recognition of individual words can be very high—at least 99 percent.

But therein lies a problem, for word-recognition devices are capable of three kinds of errors: they may match a sound to the wrong prototype, fail to recognize an acceptable word, or accept as a word a sound for which it has no prototype. A system advertised as highly discriminating—that is, responsive without error to words for which it has prototypes—may well reject so many words that its overall performance is marginal at best.

Though researchers in the field have made few recent advances, Edman is cautiously optimistic. He says there's "intense activity," especially in some high-technology industrial laboratories. Scientists now realize that to be successful, speech-recognition devices must combine conventional analysis of speech sounds with knowledge of language. Such devices must recognize, for instance, that the *principal* of a school is not the same word as a *principle* of science. Linguists and psychologists are now joining engineers to form multidisciplinary teams.

But don't start rehearsing the commands you will give your new computerized companion—yet. For the time being, Edman says, computers capable of receiving verbal inputs will be expensive, have small vocabularies, be speaker-dependent, and probably be custom designed for each application.—J.M. □

The Biotech Companies' Troubles

A couple of years ago venture capitalists were queuing at the doors of research biologists, hoping to combine their money with the biologists' savvy so that everyone could cash in on genetic engineering. But looking back, David Baltimore, M.I.T. professor of microbiology and head of the Whitehead Institute for Biomedical Research, concludes that the genetic industry was "born in naivete."

"The scientists—and certainly I myself—were unprepared for the realities of the business world," Baltimore, who won the Nobel Prize in 1975 for his work in genetic engineering, told the Boston Chamber of Commerce. "Many of us believed that good science alone was sufficient to generate products." It was not. Robert Swanson, president of Genentech, a genetic-engineering firm, has said that of the 200 biotechnology companies in business today, maybe 10 percent will survive independently.

The technique the scientists and venture capitalists were banking on is cloning. In cloning, the gene that tells a cell to produce a particular protein—such as the gene from the human pancreas that directs insulin production—is transferred into another cell. The receiver

cell, usually a bacterium or yeast, is then able to produce the protein. To harvest commercial amounts of protein, researchers thought they would merely have to grow the genetically engineered bacteria and yeasts in quantity, using fermentation technology mastered long ago in making wine, beer, and bread. The promise of such simple protein production brought investments of at least \$500 million into biotechnology companies.

But it turned out that the basic research everyone was eager to cash in on hadn't been completed. There were two problems.

First, the neat dovetail of genetic engineering and fermentation wasn't so neat. "There's a hang-up in the whole magnificent scheme," said Baltimore. "When you put a gene into a milieu in which it did not evolve, you suddenly find a mismatch between the structure of the protein being made and its surroundings. Sometimes the gene is degraded, and sometimes the cell simply turns over and dies."

Second, although biologists know how to clone many proteins, they frequently discover that they don't understand what they are cloning. For example, interferon, produced by the body's immune system, has been used as a drug. But not until it was cloned did scientists realize that there were many kinds of interferon, some of which are of little use. That realization will cost millions. "To produce a substance and then to

have to learn what it is you've got, what it does, and how to use it—that is a long and difficult way to make a buck," Baltimore said.

Solving the scientific problems is only one, albeit large, part of the business of genetic engineering. The other part is running the business. "We were all ivory-tower scientists ten years ago," said Baltimore. The obscurities of financing, marketing, and management still elude them.

The most obvious promise for biotechnology is in making drugs, but the new research companies are discovering that they lack the resources for the pharmaceutical business. Not only do large drug companies have the scientists and labs to do genetic engineering, but their marketing operations are in place, and they know their way through the expensive approval processes required by the U.S. Food and Drug Administration.

According to Gabriel Schmergel, president of Genetics Institute in Brookline, Mass., the capital requirements for even a pilot fermentation plant are in the millions, and for a large-scale operation they will run up to \$100 million. That figure does not include development, testing, and marketing. The major drug companies allot a total of \$100 million to \$300 million for all phases of a project, said Schmergel.

Had biologists been aware of what it would take to compete, said Baltimore, few would have gone into business for themselves. Today

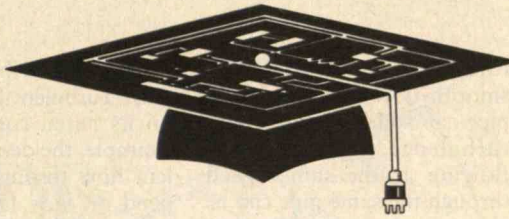
only a few of the biotechnical firms are prepared to develop and market their own genetically engineered drugs.

But there is still room for small biotechnology companies to do specialized research and development, said Baltimore. For example, Collaborative Research, whose scientific advisory board Baltimore heads, has recently cloned the gene for rennin under contract to Dow Chemical Co. This enzyme, commonly called rennet and produced in a calf's stomach, is used in cheesemaking. At other small companies, the search is on for industrial proteins that make ethyl alcohol from biomass. This process does not require expensive drug tests, and the product would be easier to market than a drug. Other possibilities include modifying living plants and making enzymes that separate desirable minerals from ore.

The cloning technique is so common today that commercial success requires selecting the right target, says Orrie Friedman, president and founder of Collaborative Research. And not only target products, but target markets. Ironically, the best markets for small genetic-engineering firms may be the industrial giants that they are unable to compete with head to head. Genetics Institute is negotiating to enter just such a joint venture. Success may not mean beating the big pharmaceutical companies, says Baltimore, but joining them instead.—Sara Jane Neustadt



Microelectronics: Industry Meets Academe



Faced with challenges from abroad, the microelectronics industry is pouring millions of dollars into new types of research centers at Stanford University, M.I.T., the University of California at Berkeley, and other campuses across the country. Unlike industry financing of biotechnology research at universities, the new microelectronics centers have met with little controversy. The universities have emphasized that research at these centers will be mostly generic and the results will be shared among several, perhaps dozens, of sponsors. This minimizes the likelihood that discoveries will be developed directly into highly profitable ventures that could divert professors from teaching and research. And there is broad agreement that without innovative efforts to improve industry's access to basic research, America's edge in high technology will erode.

Stanford's new Center for Integrated Systems (CIS) has a three-year budget of over \$13 million from industry sponsors such as General Electric, TRW, Hewlett-Packard, Xerox, IBM, Intel, ITT, GTE, and United Technologies, each of which paid \$750,000 to join. An additional \$8 million came from the Department of Defense (DOD). M.I.T. is committed to establishing a \$21 million microelectronics/integrated-systems teaching center, and though the funding is not complete, industry has provided nearly \$7 mil-

lion so far.

Gathered in such laboratories are university specialists in areas ranging from software engineering to solid-state physics, working to etch their integrated concepts onto integrated circuits. Industry sponsors receive prepublication reports of research results and sometimes send their own scientists to work in the academic environment.

Just as attractive to industry is the chance to look at the 100 master's and 30 doctoral students that will graduate from the center each year. As CIS codirector James Meindl of Stanford puts it, the sponsors will get a "lead time" not only in research but in "making connections" with the best graduate students.

Meindl expects the presence of scientists from industry to benefit the university as well: "We'll know much more precisely and fully ... the problems those companies are facing. I think we'll have a better opportunity to target our long-range research to have an impact ... on those problems."

Meindl insists that industry involvement at CIS will not harm Stanford's academic integrity because the university demands that all research—with the possible and worrisome exception of DOD-sponsored work—remains public. James Gibbons, professor of electrical engineering at Stanford, says visitors will work on problems chosen by Stanford rather than by their companies, although the companies can make suggestions.

The role of CIS, says Gibbons, is to provide global knowledge of the industry without which "true discretion in choosing important problems is severely limited."

Stanford is also concerned that "access to membership in industrial-affiliate programs should be available equally to all companies prepared to meet the obligations of membership." But at \$750,000 to join the CIS, companies with limited basic research budgets, especially small or new companies, are unfairly denied access, some critics say.

Smaller companies stand a better chance at other places. M.I.T., for example, is counting on smaller companies to participate by funding many of its center's future operating expenses. In the University of California's MICRO program, paid for by state appropriations and industry contributions, each project is individually supported by an industry sponsor. Sums required for participation are smaller, mostly in the tens of thousands of dollars. "We're especially striving to get smaller companies in," says George Turin, head of U.C. Berkeley's Electrical Engineering and Computer Science Department.

That effort has been successful. The MICRO program involved 25 California companies, including some such as Apple Computer and Hughes Aircraft, which would not be likely to participate in the more expensive CIS program. Many more companies have applied to join in the second year.

Perhaps the most telling evidence of the program's success is the state's response. The California legislature voted to more than double MICRO research grant funds, from \$800,000 to \$1.7 million, at a time when virtually all other university support has been frozen or cut back.

Other state governments, notably in Arizona, Minnesota, and North Carolina, are also funding industry-university projects in hopes of attracting new high-technology businesses eager to mine academic resources.

It is too early to predict what effects these new research centers will have on American universities. Some observers fear that university dependence on industry will inevitably skew research toward projects with foreseeable payoffs. Others worry that the prestige and financial resources of such supercenters as Stanford's and M.I.T.'s will distort the university's function as a center for learning in all disciplines. Another disturbing possibility is that fewer ideas sprouted in university laboratories will take root as new commercial enterprises, because established companies will already know of the research results.

But industry-sponsored research centers are a seemingly inevitable response to present economic conditions. Applying high technology in designing, manufacturing, and marketing new products is becoming increasingly complex, according to Gerald L. Wilson, Dean of M.I.T.'s School of Engineering. "Here, as nowhere else," he says, "is the greatest need for stronger cooperation between our academic and industrial institutions."—*June Kinoshita* □

The Weather Forecaster's Despair



In this world of technological precision, why should the weather be so difficult to predict? Forecasts for the coming day or two can never be more accurate than percentage guestimates—witness the “70 percent chance of rain.” Long-term forecasts for the coming month or season are so uncertain that England’s meteorological services have given them up. And for good reason, according to Michael Proctor, professor of applied mathematics and theoretical physics at the University of Cambridge.

Except in areas with stable climates such as deserts, he says, forecasting the weather more than a day or two ahead will always be impossible. The reason lies in the fact that turbulent air flows determine the weather.

There are two types of fluid flows in gases and liquids. Laminar flow is regular and steady, as in water running smoothly through a trough or smoke carried evenly by a light breeze. Turbulent flow is full of unpredictable eddies, as in swirling cloud formations or waves breaking. A laminar current in a river can pass undisturbed by the white

turbulence at a rock. And smooth-flowing water in a pipe can suddenly break into turbulence. Indeed, water flowing at the same speed through the same pipe can be either laminar or turbulent, depending on minute disturbances. The transition between the two states is abrupt, and neither has anything to do with the other.

The paradox about turbulence is how predictable it is. It has a definite structure: the general form of a curl of whitewater is stable. However, the details are unstable and unpredictable—the precise configuration of drops in a curl of whitewater is impossible to foretell. Unfortunately, one must know the details of turbulence to predict the weather. It is safe to say that Arizona will be hotter than Alaska in the summer and will have less rainfall than the Amazon basin. But exactly what to expect at a given moment is another matter.

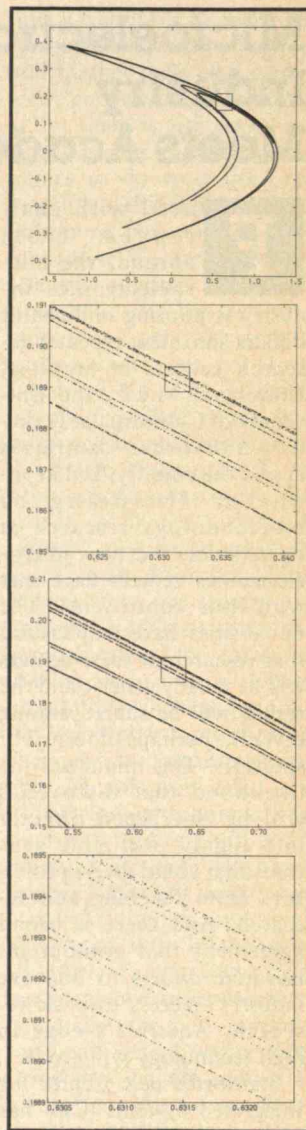
Attempting to describe turbulence mathematically, Proctor came up with “strange attractors”—graphs of various shapes such as distorted circles, doughnutlike forms, and leafy structures. All have one thing in common: they look orderly on a large scale, rather like a smooth river bed from an airplane. But on a smaller scale, disorders appear, like little rivers leading into the larger one. One strange thing about strange attractors is that the little rivers have the same overall shape as the large river—as do streams flowing into the little rivers, trickles running into streams, and so on forever. But the closer one looks, the more disorder appears.

The problems of foretelling the details of a turbulent flow—and hence weather—

can be described another way. Turbulent flow depends on its initial conditions. For example, the details of turbulent flow through a pipe depend on how fast water enters and how disturbed it is. Suppose forecasters could calculate, given the turbulent flow of the atmosphere on any one day, what the turbulent flow and hence the weather would be the next day. “Iterative” equations, starting with initial numbers describing current weather, would generate numbers describing weather for following days.

To take a simplified case, consider the numbers between 0 and 1, and suppose that low values mean rain, high values sun. Say current weather conditions, x_0 , are fairly rainy—.2. Actual iterative equations to predict the weather would be complicated, but suppose for simplicity you could get the next day’s weather, x_1 , merely by applying the equation $x_1 = 3.9(1-x_0)x_0$. In other words, $x_1 = 3.9(1-.2).2$ or .624—moderately sunny. You apply the same iterative equation to get the following day’s weather: $x_2 = 3.9(1-x_1)x_1$. Then $x_2 = 3.9(1-.624).624$ or .915—very sunny. And so on. (These equations have been described in *Scientific American* by Douglas Hofstadter.)

Can one accurately forecast 100 days ahead? Not if one makes a mistake in the value of the initial number (0.2) by one ten-thousandth. This is easy to do, since the instruments used to measure atmospheric conditions of temperature, wind, and humidity can never be perfectly accurate. After 20 iterations, representing 20 days, the error would be so large as to turn high values into low or vice-versa—predicting rain



Successive enlargements of a “strange attractor” (from top to bottom) are like a doll within a doll within a doll. The general pattern is clear, like the pattern of seasons, but the location of a particular point is unpredictable, like the weather at a specific moment. (Diagrams: Communications in Mathematical Physics and M. Hénon)

instead of shine.

Nor is that the worst of the matter. One must use a computer to calculate these answers, and computers have only limited accuracy. With numbers rounded off by the computer, a large error arises in the prediction after only a few iterations, or days. Furthermore, weather equations are far more complicated than in this simple analogy.

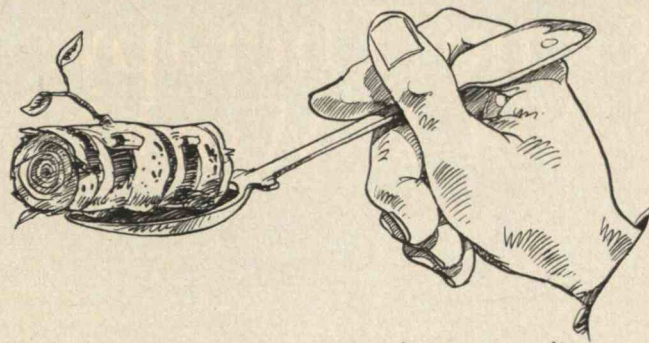
Proctor says that his argument does not prove that weather prediction is impossible. But it strongly suggests that forecasters have an unenviable job. Proctor quotes Sir Horace Lamb, the English fluid mechanicist. "I am an old man," Lamb said at the end of a long life. "When I die and go to heaven there are two matters on which I wish for enlightenment. One is [the theory of relativity], and the other the theory of turbulence. About the former I am really rather optimistic."

—Katy Bridges □

Chemistry's New Sweets

One lump or two? Once upon a time, that was the chief decision one had to make before sweetening a cup of tea. But now sucrose, the traditional sugar refined from beets or cane, is slowly relinquishing its hold on America's sweet tooth. Aspartame, a low-calorie challenge to saccharin that recently came on the market, may spur the introduction of a host of other new sweeteners. Many have been developed but still must survive the long, costly regulatory process.

Saccharin, on the market since it was first patented in 1885, never seemed to be the



ideal alternative to sugar. President Theodore Roosevelt convened the first panel to review charges against the safety of saccharin in 1911, and a ban on the sweetener was advised but never put into effect.

Sugar rationing during World War I and then World War II caused an increase in saccharin use. Studies linking saccharin to bladder cancer in male rats began to appear in the 1970s, and in 1977 the Food and Drug Administration (FDA) proposed a saccharin ban. However, Congress has voted every two years since to extend a moratorium on the ban, and recent major studies, such as the National Cancer Institute review of 9,000 users, have failed to confirm a link between saccharin and cancer.

A shadow also hovers over aspartame—the leading contender to replace saccharin, in that typical daily consumption is expected to be hardly more than three calories. The FDA approved aspartame for human use in spite of a controversial study linking it to brain lesions in animals.

Aspartame is synthesized from two amino acids that form naturally when bacteria break down organic substances. Its primary advantage over saccharin is its lack of bitter aftertaste. Aspartame is more expensive—over 20 times the cost of saccharin—but biotechnology may soon make produc-

tion cheaper, according to a representative of G.D. Searle & Co., the manufacturer.

Meanwhile, the search for new and better sweeteners continues. A major problem, according to Lyn O'Brien and Robert Gelardi of the Calorie Control Council, is the complexity of human taste mechanisms. "The chemical structures of known sweeteners are so diverse that it is difficult to predict which chemical will produce sweetness," they explain in *Chemtech*. Thus, some researchers are attempting to synthesize compounds similar to those found in sweet plants, while other scientists have discovered sweeteners purely by chance.

Neo-DHC, approximately 1,500 times sweeter than sucrose, is promising, and stevioside, a stable and soluble low-calorie sweetener, is already being used in many Japanese products. But stevioside still has to go through a \$3 million to \$5 million testing process to get FDA approval before being sold in the United States. According to a representative of its supplier, Atomergic Chemetals, "No one's willing to put up that kind of money, and the same goes for neo-DHC."

Acesulfame K, a West German product, seems to be furthest along in the regulatory process. And an English product, Talin, has been approved in Japan. Xylitol, a

Swiss-made caloric sweetener used in Europe, has the advantage of not causing—and perhaps even preventing—cavities.

Despite their pharmaceutical-sounding names, these sweeteners and many others in various stages of research and regulation are extracted from natural substances such as birch wood (xylitol), orange and grapefruit rinds (neo-DHC), the leaves of a Paraguayan plant (stevioside), licorice root (glycyrrhizin), and various fruits of West African plants (talin, monellin, and miraculin). Thus, the term "artificial sweetener" is really a misnomer—many sugar substitutes are natural.

Furthermore, what people think of as natural sugar—table sugar—not only boosts calories and causes cavities, but may contribute to heart disease and diabetes, according to Dr. Sheldon Reiser at the U.S. Department of Agriculture's Carbohydrate Nutrition Laboratory.

Furthermore, fructose—the sugar found in fruits and vegetables—is probably worse. In the form of corn syrup, it makes its way into products such as salad dressing, canned fruits, catsup, and beverages. "We're very concerned," says Reiser. "High-fructose corn syrup may be promoting both heart disease and diabetes."

Of sweeteners available as additives, aspartame seems to have the cleanest bill of health, Reiser says. Since it breaks down into amino acids, the building blocks of proteins, it is unlikely to be carcinogenic, while saccharin may be. A good time-honored source of sweetness is fruit, Reiser says. "At least you get fiber and other nutrients along with sugar."—Susan Katz □

Gene Therapy: Will It Work?

BY TABITHA M.
POWLEDGE

WHEN Martin Cline tried to cure an inherited blood disease in the summer of 1980, he didn't know he was risking his medical career. Cline wanted to transfer normal genes for hemoglobin into the bone marrow of two young women suffering from beta thalassemia, a genetic disorder that kills most of its victims by early adulthood. Thalassemia is caused by a mutation in the gene for hemoglobin, the oxygen-carrying ingredient of red blood cells. The mutation produces brittle red blood cells unable to carry enough oxygen to essential parts of the body.

A few months before, Cline, a specialist in blood disorders, and several colleagues at the University of California at Los Angeles (UCLA) had transferred a different gene into the bone marrow of mice. Since red blood cells are made in bone marrow, this suggested a possible way to cure inherited hemoglobin disorders, the best-known of which are thalassemia and sickle-cell anemia. If a gene for normal hemoglobin could be inserted into a patient's bone marrow, the marrow might begin to produce normal red blood cells. In effect, the disease would be cured.

So Cline applied to the UCLA Institutional Review Board for permission to try inserting a normal hemoglobin gene into the bone marrow of sickle-cell patients. But before the board reached its decision, Cline attempted the technique on two

thalassemic patients, one in Italy and one in Israel. Shortly thereafter the board denied his application, mostly on grounds that he needed to do more animal experimentation before he began trials with humans. That fall, the *Los Angeles Times* revealed Cline's work abroad, provoking enormous controversy. The upshot: Cline was formally censured and forced to resign as chief of hematology/oncology at UCLA. He also lost two of his four federal grants, totalling more than \$190,000.

The reaction might have been different had his experiments abroad been successful, but they were not. Many scientists interpreted his punishment as a warning to refrain from applying gene therapy prematurely.

Despite Cline's apparent lack of success, the genetic engineering of a patient's own bone-marrow cells remains the most promising prospect for gene therapy in

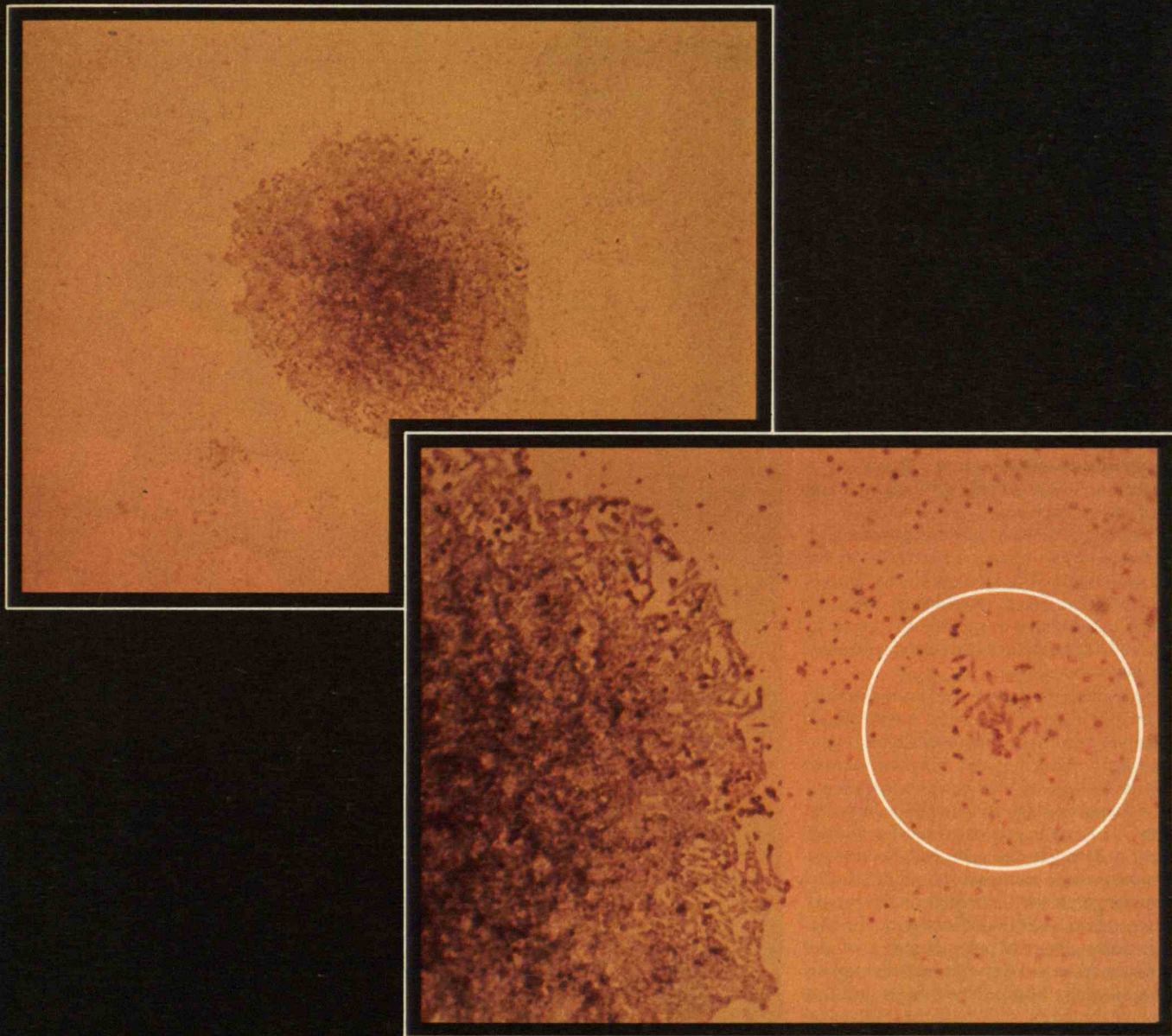
TABITHA M. POWLEDGE is completing a book on current developments in human genetics entitled *The Last Taboo* (Houghton-Mifflin). She was formerly a consultant to the President's Commission for the Study of Ethical Problems in Medicine and Biomedical and Behavioral Research.

hemoglobin disorders. The technique may also lead to cures for other genetic diseases: many scientists are hoping that replacing a "bad" gene with a "good" gene will eventually cure at least a few disorders resulting from mutations in a single gene. Furthermore, this research will deepen our understanding of how genes work and what turns them off and on in each cell.

There are no precise statistics on the extent of genetic disease. Genetic abnormalities probably account for a great many spontaneous abortions and infant deaths, as well as a substantial proportion of serious childhood disease. For example, the National Academy of Sciences recently estimated that 10.5 percent of all newborns have serious genetic defects. And hemoglobin disorders kill an estimated 200,000 children a year worldwide, according to the World Health Organization.

However, individual inherited disorders caused by a single gene are usually quite rare. Tay-Sachs, a degenerative disease of the central nervous system that is fatal in early childhood, affects at most a few dozen infants a year in the United States. But genetic disease is not confined to disorders of single genes, or even to abnormalities of the strings of genes known as chromosomes, such as Down's Syndrome. Genes, along with environmental factors, are also implicated in pathologies we

Despite many obstacles, gene therapy—the process of replacing a “bad” gene with a “good” one—may one day provide cures for some genetic diseases. But its real benefit may be what it teaches us about the basis of life.



One way of getting a healthy gene into diseased human cells is to use a virus as transport. In an attempt to cure Lesch-Nyhan, a rare neurological disorder, researchers have hooked the normal gene up to a piece of viral DNA. Here, they have inserted the

fused gene into a colony of Chinese hamster cells infected with a disease similar to Lesch-Nyhan (as shown in the upper figure). The result (as shown in the lower figure): the corrected cells are taking over and the clump of diseased cells (circled in white) are dying.

usually don't think of as genetic. Among these are mental conditions such as depression and schizophrenia, diabetes, and many kinds of heart and circulatory diseases.

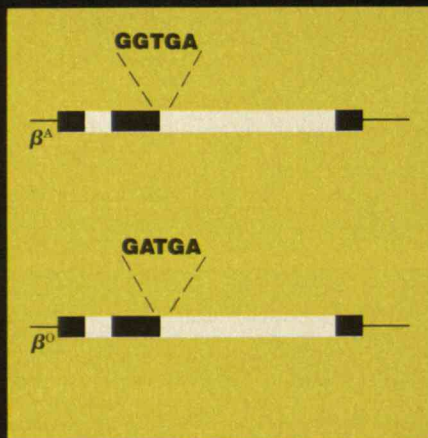
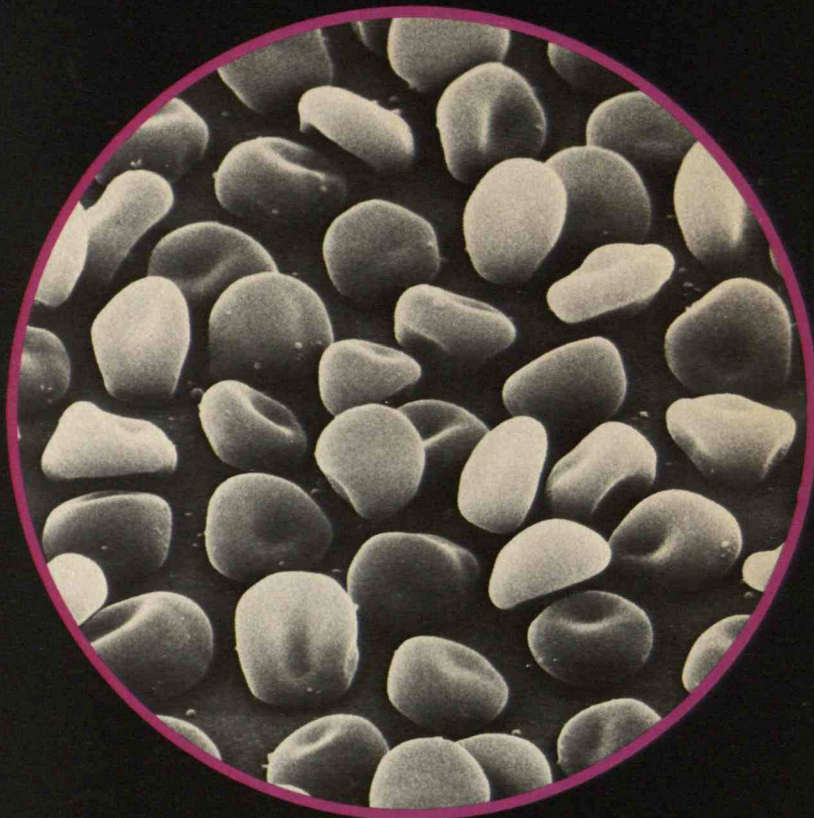
The assumption behind Cline's kind of gene therapy is that the few cells genetically engineered to produce normal products will proliferate and overwhelm their defective kin. But this technique is applicable only to tissues that grow and divide continuously, such as bone marrow, skin, and intestinal cells. The problem with this approach is that many genetic diseases affect tissues that do not proliferate, such as those of the nervous system. Curing these disorders would require transferring "good" genes into all, or at least most, of the cells of the target organ. Researchers would then have to figure out how to get the genes to function properly in each cell.

One way of accomplishing this may be to use a virus to carry a new gene to the affected tissue. The virus, with the "good" gene inserted into it, would then infect the tissue and behave as viruses do, replicating and manufacturing whatever product the gene codes for.

This method, called viral transduction, is an old dream of genetic engineers. A group headed by C. Thomas Caskey, professor of medicine and biochemistry at Baylor College of Medicine, is exploring it as a possible cure for Lesch-Nyhan disease. This neurological disorder results from a defect in the gene for the enzyme hypoxanthine-guanine phosphoribosyl transferase (HPRT), essential to the breakdown of uric acid. Children with the disease suffer from hyperexcitability of the nervous system. They mutilate themselves compulsively, biting their fingers and lips despite the pain.

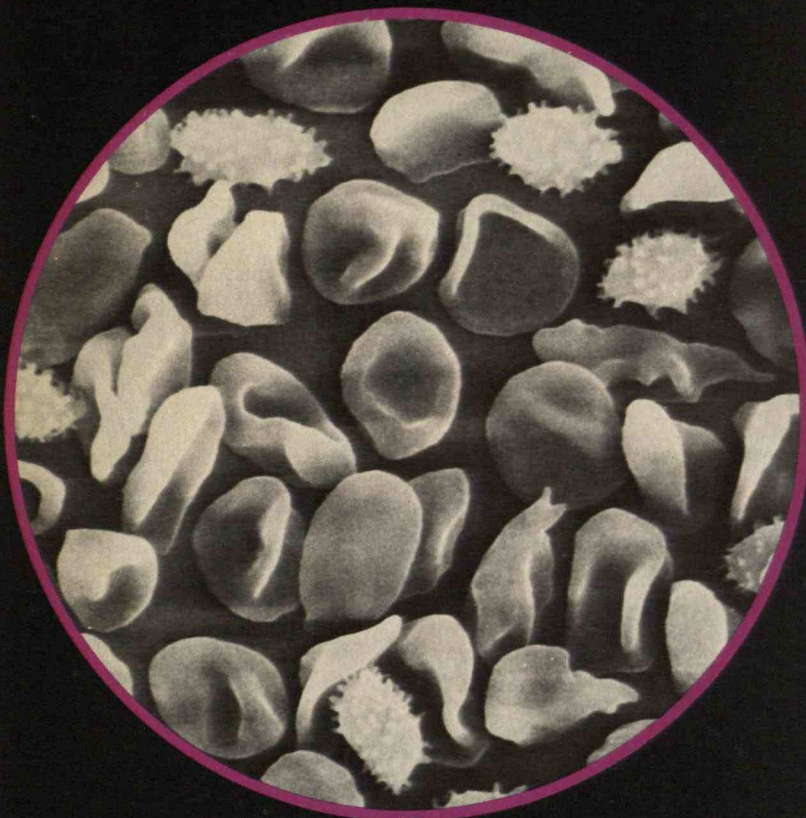
Caskey and his colleagues have been able to insert an HPRT gene, along with a piece of viral DNA, into cells in culture in the laboratory. They are now investigating whether the gene makes HPRT and in what amounts. But to achieve a cure for Lesch-Nyhan, they will probably have to use a virus that specifically invades the brain. Unfortunately, two promising candidates—the Coxsackie virus and the one that causes encephalitis—are anything but desirable residents of that organ, leading to inflammation, brain damage, and death. The chosen virus will have to be made incapable of causing disease while retaining its ability to infect the brain,

The only difference between normal red blood cells (magnified 5,400 times at the left) and deformed blood cells found in sickle-cell anemia (right) is a mutation in the gene that codes for he-



Minute sequences of DNA can be isolated and examined with a technique that uses enzymes like scissors, called "restriction endonuclease analysis." Here it reveals the one difference between a normal hemoglobin gene and the defective hemoglobin gene that causes one type of thalassemia, a blood disorder. In the normal gene (β^A in the top bar), the chemical letters or nucleotides in the specific DNA sequence are GGTGA. In the defective gene (β^0 in the bottom bar), the nucleotides are sequenced as GATGA. The single difference is the substitution of one nucleotide (A) for another (G).

moglobin, a protein inside the cells. This mutation produces sickled cells that get clogged in the tiny blood vessels of the body and are unable to carry oxygen to vital sites.



At present, genetic disorders can be prevented only by screening and counseling couples at risk of carrying the defective gene. Here, a patient is tested at the University of Miami for sickle-cell anemia, a blood disorder that among Americans primarily strikes blacks.

replicate itself (along with its new gene), and produce HPRT in the proper amounts. Caskey concedes that it's "a pretty tough problem," but he expects to see some progress in the next three to five years.

Mighty Mouse and Other Expressions

So far researchers in gene therapy have concentrated mostly on ways of delivering a "good" gene to the proper place in the body, but that is only the first technical problem to be solved. The second, far more difficult, problem is to figure out how to get the "good" genes to behave as they should once they've arrived in the target cells. This means finding out how genes work and what controls them in living creatures.

Most of the work potentially relevant to gene therapy has been done in mice. Several research teams have successfully inserted foreign sequences of DNA, or genes, into fertilized mouse eggs using a hollow glass needle thinner than a hair. Though delicate, this microinjection technique often destroys many of the eggs. Those that survive are then implanted into the uteruses of surrogate mouse mothers and, if all goes well, survive to become parents themselves.

A number of research groups have been able to identify the transferred DNA sequences in mice as they develop from the injected eggs. Because the foreign DNA is transferred into a fertilized egg, it is present in all the cells descended from that egg—that is, throughout the resulting mouse. This means that the new gene appears not just in blood, brain, skin, and liver but also in the germ cells—the eggs and sperm that will give rise to subsequent mouse generations. In short, the new gene can be inherited.

Only three teams have so far claimed success in transferring a foreign gene into a mouse and getting that gene to express itself; that is, produce a product. The most spectacular progress has come from a group led by Richard D. Palmiter of Howard Hughes Memorial Institute Laboratory at the University of Washington and Ralph L. Brinster of the School of Veterinary Medicine at the University of Pennsylvania.

Last December, they reported introducing a gene that controls the production of growth hormone in rats into mouse eggs. The mice born with the new gene grew much faster and larger than littermates

Researchers have finally succeeded in getting a gene from one species (rats) to express itself in another species (mice). The result: "mighty" mice that are twice the size of normal mice.



without the gene—at 10 weeks one mouse was almost twice as big. The gene was also inherited by 10 of the 19 progeny born to one of the genetically engineered mice; the 10 offspring grew bigger too. This marked the first time genes transferred into a mammalian embryo resulted in obvious metabolic change.

The researchers now hope to use their technique to cure dwarfism in a strain of mice deficient in growth hormone. Eventually, say Palmiter and Brinster, the gene transfer method might also be used to develop new breeds of domestic animals that would grow rapidly and produce larger quantities of meat and milk.

Although others praise this group's work, the experiments illustrate how far scientists are from the goal of controlling gene expression in mammals. In the "mighty mouse" experiment, for instance, the inserted gene made large quantities of rat growth hormone in the liver. Normally, growth hormone is produced in the

pituitary gland. "We are still a long way from controlling the gene," Brinster notes.

Human Engineering

The genetic engineering of mammals hints at a kind of human gene therapy different from genetic manipulation of specific tissues. Might it someday be possible to cure genetic disease by inserting normal genes into a human embryo? In fact, might that not be the only way to cure inherited diseases in which a number of different parts of the body are damaged? For diseases that invade several organs, genetically manipulating specific tissue after birth may be pointless.

Most scientists insist that though genetic engineering may be used on domestic animals, its application to human embryos is unthinkable. If other moral concerns are not enough to prevent human experimentation, many scientists say, safety concerns are. (See "Genetic En-

gineering: Life as a Plaything," page 14.)

For example, in the mice experiments, no more than 10 percent of the fertilized mouse eggs survive microinjection, and researchers say that society would never tolerate that survival rate in human eggs. Furthermore, inserting genes can harm those mouse embryos that survive the initial trauma of microinjection. In September 1980, Frank H. Ruddle and his colleagues at Yale University were the first to announce publicly that they had successfully transferred foreign genes into mice by microinjecting them into fertilized eggs. But only the eggs that developed into females went on to have offspring; the males were sterile. Gene injection interfered, in some unknown way, with sperm production.

Although mammalian genetic engineering will not be applied directly to human embryos, according to many scientists, it will benefit humanity indirectly—in the form of information about gene expres-

sion and regulation. This information may eventually contribute to improved methods of dealing with genetic disease.

Scientists have already used the knowledge gleaned from another kind of basic molecular research to treat a patient with thalassemia. Last December, scientists at the National Institutes of Health (NIH) and the University of Illinois College of Medicine reported using the drug 5-azacytidine in this patient to switch on the gene that manufactures hemoglobin in the fetus. The "turned-on" gene produced enough normal fetal hemoglobin to compensate temporarily for the patient's abnormal adult hemoglobin. Normally, fetal hemoglobin production shuts down in childhood when adult hemoglobin begins to take over. Although scientists have no information about the long-term effects of this experimental treatment, turning fetal hemoglobin back on in patients with adult hemoglobin disorders may help them lead essentially normal lives.

This development highlights the "many recent contributions that have made the principles of molecular genetics relevant to present-day diagnosis and treatment," notes Edward J. Benz, Jr., of Yale University School of Medicine, in a recent issue of the *New England Journal of Medicine*. "It was not necessary to attempt to remodel the patient's genome [genetic structures] by excising the 'bad' genes or inserting 'good' ones in their place."

Hurdles to Overcome

Although such "remodeling" is the primary thrust of gene therapy, its development is strewn with obstacles. First, as Bob Williamson of St. Mary's Hospital Medical School at the University of London has pointed out, there are more than 2,000 single gene disorders, and they are so diverse that most will require unique and idiosyncratic therapies. Furthermore, many are so rare that the benefits of gene therapy, if it can be achieved, may not warrant the expense, Williamson says.

Moreover, gene therapy is possible only for diseases for which the defective gene and its normal counterpart have been identified. Ways must still be found to copy normal genes in the laboratory so there will be enough to genetically manipulate and administer.

In addition, the inserted gene must function properly once inside the cell and direct the production of its normal prod-

uct in amounts sufficient to cure the disease without harming the patient. This final step requires detailed knowledge of how genes manufacture proteins and what turns them on and off—knowledge that is likely to be some time in coming.

Even when researchers have developed a therapy for a particular disease, clinical trials in humans can begin only after extensive trials in animals. All these criteria are likely to be observed stringently, particularly because previous attempts at gene therapy have been unsuccessful and highly controversial.

Finally, gene therapy may turn out to be applicable only to genetic disorders caused by a single defective gene, and only to some of those, Williamson points out. The technique offers no way of dealing with abnormalities of entire chromosomes, nor is it likely to be useful for the most important group of diseases—such as diabetes, heart and circulatory diseases, and many mental disorders—in which both genes and environment play a role.

In short, while the first successful gene therapy will probably burst upon the medical world before long, many scientists are pessimistic. "The correction of a disease by gene therapy will be worthwhile only if there is no other simpler and more effective technique available," Williamson says.

Baylor's Thomas Caskey agrees that the uses of gene therapy will be limited. But he points out that many of the current treatments are unsatisfactory and do little more than ease the symptoms of disease.

Most victims of sickle-cell anemia, for instance, can be treated only with drugs that relieve the intense episodes of pain caused by the body's insufficient supply of oxygen. The treatment for cystic fibrosis, which causes severe respiratory and gastrointestinal problems and is usually fatal by early adulthood, is also inadequate. Treatment requires the constant use of an oxygen tent and special feeding, imposing an expensive and emotionally taxing burden on patients and their families.

Screening couples in an effort to prevent the birth of children with inherited disease is another option. But at present, there are effective mass-screening tests for only three genetic disorders: sickle-cell anemia, thalassemia, and Tay-Sachs disease.

Even for these disorders, Caskey thinks the population carrying the defective genes may be too large and ill-defined for screening programs to be cost-effective.

Only in Tay-Sachs disease is the defective gene mostly confined to a small population—descendants of Eastern European Jews. And even when thousands of people were screened for the Tay-Sachs gene in the Baltimore-Washington area in the early 1970s, the tests located only one fetus with Tay-Sachs. The potential parents chose abortion to avoid bearing a child that would shortly die.

"We're just not going to be able to prevent much serious disease by screening and prenatal diagnosis," Caskey says. "Therefore we need to put some effort into actual therapeutic replacement" of defective genes.

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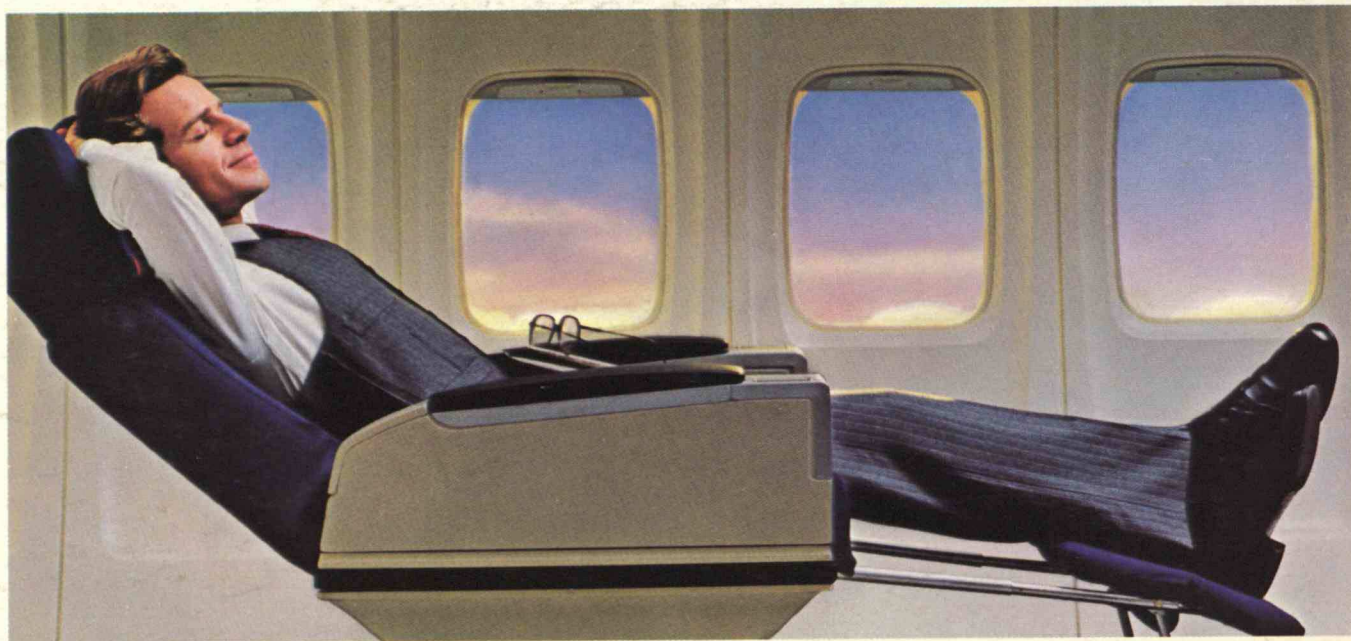
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